

Saskatchewan

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Agriculture Development Fund

FINAL REPORT

**COMMERCIAL FEASIBILITY ASSESSMENT OF
SASKATCHEWAN PLANTS DESTINED FOR
MANUFACTURING USES**

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Bio-manufacturing in Saskatchewan

**Assessment of the manufacturing potential of select Saskatchewan
plants**



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What is this report about?

Saskatchewan generates enormous amounts of plant material as agricultural crops, forest trees and "wild" species. Most of what is utilized economically from agricultural production is still exported without being processed in any meaningful way. The province's traditional exports remain grains: wheat, oats, barley, flax, canola. Yet some value-added processing of field and forest plant resources has come into existence in the province, and there seems to be a continuing determination to increase this kind of activity. The interest is to capture, within the province, the jobs and incremental value that manufacturing activities bring with them.

Fytokem Products Inc, the Saskatchewan Nutraceutical Network and the Saskatchewan Department of Agriculture and Food launched a joint 12-month project (1999-2000) to gather, generate and publish information for at least 25 plants of potential manufacturing importance and interest. The project has set out to do eight things:

1. Establish a consensus-based list of 25-30 plants of perceived potential in the province for product bio-manufacturing in the foreseeable future
2. Review the biological and agronomic characteristics of these plants, along with their costs and availability as raw materials
3. Examine presently known value-added uses of the plants and their products
4. Ascertain whether prior publications or patents exist which might constrain the development and marketing of new manufactured products
5. Measure the yields of extractive materials obtainable from each of the listed plants
6. Determine the toxicity and, especially, the cytotoxicity of the plants and their extractives
7. Provide some general guidelines on how to evaluate plants as potential resource bases for value-added production.
8. Bring the foregoing information together in a comprehensive, clearly written report equally suitable for expert and non-expert audiences

Manufacturing, Products and Markets

"Manufacturing" is an entire process - technical, economic and organizational - by which "starting materials" are transformed into "products" for specific uses. "Processing" comprises the technical parts of manufacturing; the transformation steps themselves. Manufacturing based on plants generally follows one of two routes: either plant materials are physically re-formed to give value-added products, or value-added substances are extracted from the raw plant material.

The general processes common to most plant raw materials can be summed up as follows:

- Upon harvesting, the plant material must either be processed immediately (as in essential oil manufacture) or stabilized for later processing, by drying. Large plants such as trees may not require this step.
- Dried material may need to be cleaned and extraneous parts removed (seed de-hulling, or de-branching and de-barking of trees at pulp-mills or sawmills).
- Stabilized material can if necessary be separated, shredded, milled or ground for transport and subsequent processing steps. Or a milled material may itself be the product.
- Material may be re-shaped physically by cubing, by pelletizing, or (as with timber) by cutting to make lumber or fenceposts or other formed products.
- Material may be extracted to separate out an extractive fraction from a residual fibre fraction; both fractions usually have commercial value.
- Extracts may be chemically processed to provide nutraceutical, cosmetic, personal care or therapeutic ingredients.
- Any "product" may be combined with other materials to manufacture of new products with still further inherent value.
- Finally - and not trivial - packaging and presentation will play decisive roles in determining the marketability and price of the product. Packaging is part of the manufacturing game.

Selection of Plants

Early in May of 1999, a large number of faxes, letters, emails and phone calls were expedited to primary producers, processors, research and development people, marketing and sales personnel, and various associations around Saskatchewan.

- ❖ The goal: to identify 20-30 plants in which there is active and serious manufacturing interest.

In the survey, a great many plants were put forward as "interesting" by our respondent audience. There was a truly tremendous breadth of interests! Unfortunately, in many cases there was little depth to the interests. The precise reasons why someone was "enthused" about a plant were often not clear or at least not communicated clearly. The basis for some interests seemed rather slight, and in almost every instance the proponents either were not well aware of the "innovation" pathway from idea to marketplace, or grossly underestimated the challenge and difficulties of developing and profitably marketing novel bio-manufactured products.

Still, some plants did keep popping up in responses, and these were ultimately included in the target list based on the amount of sheer interest, and not so much on their apparent practicality or feasibility. In keeping with the general terms of the contract for this research project, we shied away from studies of major crops where a great deal of excellent previous work is already available, and where larger institutional teams continually foster the use of these crops. Flax was the notable exception.

The resultant list of plants comprises 26 different species which altogether paint a panoramic spectrum of the diverse floral resources available in our province. This includes native wildflowers, cultivated crops, trees and shrubs, a lichen, and several introduced forbs and herbs. All of these plants are either naturally abundant and readily available, or are capable of being grown in Saskatchewan (this was another obvious delineator to the selection of these plants).

Our approach has been to extend rather than to recapitulate the available information, and to focus on herb and spice crops, on naturally occurring species, and on novel crops with evident emerging manufacturing uses. It is likely that some of these plants will never result in a really significant manufacturing endeavour,

but it just as important to realize the abundance of potential that is available in Saskatchewan. No doubt our set of choices will completely satisfy no one – but we hope it will prove valuable to many.

Extractions

It's been noted above that value-added products may come from plants via extractive processes. Extraction generally refers to the separation of a starting material into soluble and insoluble fractions. The "soluble" part is the extract, the "insoluble" part is the residue.

The result of any plant extraction depends on three factors:

- The nature of the material being extracted (which plant species? which plant part?)
- The particular solvent used to extract (water? alcohol? hexane? carbon dioxide?)
- The extraction conditions employed (hot or cold? long extraction or short?)

Plants are not alike in their chemical contents, but there are broad similarities. Almost all plants contain sugars, waxes, cellulose, lignin, chlorophylls, flavonoids, oils, proteins, DNA, salts and minerals. Faced with extraction solvents, these broad classes of substances behave consistently. Thus, extraction of any plant with water can be expected to bring the following water-soluble classes into solution: sugars, minerals, proteins, salts and some flavonoids. Extractions with alcohol tend to solublize chlorophyll, flavonoids, some waxes and some oils. Hexane extractions typically solublize oils, waxes and chlorophyll.

It is impossible to predict how efficiently an extraction will solublize all the available chemicals in a plant. This can be measured in the laboratory, however, by carrying out long, very complete extractions. The results are usually expressed in terms of the percentage of the plant's dry weight which has been solublized in the extraction solvent. (Remember that this figure will be different for different solvents and different plants.) Later in this report, we present data from our own laboratory extractions which – often for the first time – have measured the amount of material extractable from various plants of Saskatchewan targeted for this study.

The availability of extractive material from a plant is an important consideration in calculating the economics of an extractive

process. Obviously, if it costs \$10 000 to conduct an extraction of a tonne of raw material, a return of 160 kg (16%) of extract will be better in terms of unit cost than a return of only 80 kg (8%). In fact, only the higher return may permit a product to be profitable. So extractive yields are important data about plants destined for manufacturing

Extract information included in this report include the use of distilled water (extraction time = 2 hours) and ethanol (extraction time = 1 hour) as solvents.

Patents

In this report, we have examined all the "live" patents (that is, those issued within the past twenty years, since 1980) in the four patent jurisdictions of principal interest: the US, Canada, Europe and Japan. These jurisdictions have solid records of good practices in patent issuance and enforcement and are the most-sought-after areas of coverage for most applicants.

With plants, a great deal of patenting was done before 1980 – sometimes as far back as the nineteenth century – so that few live patents exist today. That does not mean that a particular process or application is open to patenting, or not. Inventors would have to search for pre-1980 patents and also for public domain information before knowing whether their discovery is indeed novel and patentable. Discoveries or information which have been made available publicly through publication or announcement cannot be patented subsequently. The existence of a "live" post-1980 patent, however, is certainly a barrier to new protection on the same topic. Manufacturers or product developers might instead try to license rights to exploit an existing patent, for which right the patent holder will expect some financial reward to be negotiated.

In some cases, especially on the Canadian Patent Office, patents were applied for which had not yet been granted. In these cases, the application date or the date of patent examination was recorded. As well, where plants had an exceedingly high number of patents, these were not all included. In these cases, those thought most relevant or representative of the spectrum of applications were included.

The nature of patent protection

A patent is a monopoly right, granted by a national government to inventors. This right allows inventors to exploit their invention commercially without competition for some period (generally 20 years). Inventors may choose to license their patent to one or more "licensees" who then have preferred positions in the marketplace. Or inventors may assign their right to some other entity such as their employer; and often, companies employing inventive staff require such assignment as a condition of employment.

Pros and cons of patenting

To obtain a patent on an "invention" an applicant must demonstrate to the satisfaction of the government's patent examiners that the "invention" is novel, useful (exploitable commercially), and non-obvious. This last condition prevents frivolous applications.

The requirement for exploitability underscores the intensely commercial nature of patents. The requirement for novelty is at the heart of every patent case. The first person to file an application for a patent is the first case to be considered for that patent. If an inventor is foolish enough to disclose his invention prematurely to others without a requirement of confidentiality of their part, any of those others may apply for a patent and be considered ahead of the inventor himself. That's the law.

Patenting is an attractive idea, but there are downsides. First, it takes effort and costs money to get a patent, often from \$5,000 to \$10,000 initially and more later in maintenance fees. Second, between an application and the granting of a patent, two to five years may elapse during which there is no effective protection of the invention. Third, there is always significant risk that the government's patent examiners will judge some claims to protection to be inadmissible, so that in the end the applicant will not get what was intended in the way of protection.

As suggested above, patent applications may delay publication of results about the invention and also of news of the invention. Finally, since each country governs its own patent regime, a Canadian patent will not protect an invention from exploitation in the United States or France or South Africa. Coverage must be obtained separately in each country. Most (not all) countries do cooperate through an international Patent Cooperation Treaty.

Even if a patent is issued without any undue difficulties, there remains the spectre of litigation. This is an especially serious problem for individuals and small companies, as in Saskatchewan for example, for they lack the resources to litigate. A large company may infringe a patent knowing full well that the patent holder is financially unable to defend his/her rights in court.

Requirements for a patent

That said, patents may be obtained for two kinds of "invention". On one hand are the so-called applications patents (or composition-of-matter patents; or Class A patents) which describe how some thing can be useful in some particular purpose. This class of patent would take in such inventions as: "use of willow leaf extracts as skin conditioners" or "medicaments from flax plants" or "anti-microbial preparations from plants of the legume family".

On the other hand are so-called process patents (or Class B patents) which describe how to do something. This class would take in such inventions as, for example: "a new method for drying plant materials" or "a new synthesis of steroid hormones" or "an improved process for separating oil from water".

Inventors make claims to particular aspects of their inventions when they apply for patents, and whichever of these claims are allowed by the patent examiners then become part of the patent document. If no claims are allowed, no patent issues.

Searching for patent information online

Patent attorneys have traditionally been the ones who perform searches for clients. Nowadays, if you have access to the World Wide Web, you can search for patent information yourself, at these sites:

Canadian Intellectual Property Office:
<http://patents1.ic.gc.ca/intro-e.html>

US Patent & Trademark Office:
www.patents.uspto.gov/patft/index.html

Intellectual Property Network (includes European and Japanese patents):
www.patents.ibm.com/

Japanese Patent Office:
www.jpo.miti.go.jp/

Cost & Availability of Plants

As some of the items on the target plant list are not commercially traded on a large scale, some price estimation was required. In the case of every plant, an attempt to obtain at least two prices was made.

When plant material could not be obtained commercially in Saskatchewan, an attempt to source the material outside of Saskatchewan was made. An actual or potential supplier of material is listed at the bottom of most species' pages.

Since the bio-active compounds sought by "plant actives" processors are sometimes confined to certain parts of plants, or because it is not ethical to harvest large numbers of some wild plants, or because it is not economically feasible to separate twig bark from fine woody twig material, the study report price section defines certain parts of plants and their level of primary processing. All prices listed are for air-dry botanicals. All prices quoted are in Canadian dollars, f.o.b. farmgate or wildcrafter's storage site. Prices include bagging or baling.

Definitions are as follows:

- **Aerials:** Aerial portion of plant that can be harvested at any time of year (*Cladina* spp.)
- **Barks:** Outer and inner bark together, either whole strips or milled. No dead woody material.
- **Conventional:** Price quoted for conventionally grown plant material, either with chemical herbicides and fertilizers or organically grown.
- **Certified organic:** Price quoted for plant material that is certified by an organic certification agency (such as the Organic Crop Improvement Association) as having been organically grown and dried according to their international standards. Material is also certified as having no genetically modified inputs or seed genes.
- **Dry:** Below 10-12% moisture content. May be sun-dried, air-dried or freeze-dried.
- **Flowering aerials:** Includes the stem, leaf and flower of plants cut slightly above surface of soil or water (alfalfa). Material

can be dried in field or collected and dried under shelter. Material often baled.

- **Fruit-bearing aerals:** Above ground/water portion of plant with berries or fruiting bodies present.
- **Leaf only:** When buyer specified leaf only (cilantro, labrador tea, etc.) the price is higher than leaf and twig (red-osier dogwood, caragana). This material is either picked clean from the twig at harvest time, or manually or mechanically processed to separate the leaf only the leaf material is dry.
- **Common name:** A plant's common name varies from locale to locale, but is part of the vernacular of plant commerce. For example, trembling aspen and white poplar are both correct common names for *Populus tremuloides*.
- **Latin binomial:** The scientific name given to plants by botanists. Includes genus and species. For example, *Picea* is the genus for spruce trees and *glauca* in Latin means white. Therefore, *Picea glauca*, usually underlined or italicized, means white spruce tree to botanists and foresters in every language on earth.
- **Leaf and twig:** Twigs are pruned from trees and shrubs and dried with leaves on. Maximum twig diameter, dry, is 5 mm.
- **Milled:** Material passed through a hammer mill with screen size determined by buyer. For example, bark strips (whole) are milled into chips via a 12 mm screen.
- **Root crops:** Means tap roots and fibrous root systems and rhizomes. Essentially anything growing below the surface of soil or water. Trimmed to exclude stem.
- **Seed on stalk:** In the case of stinging nettles, where seed and seed coats are attached to a fine stalk, this material is gathered and sold as seed on stalk.
- **Seed only:** The seed of plants such as flax, caraway, fruits of coriander, etc. Seed may be purchased grower-direct bin-run, in which case it contains a percentage of weed seeds, or it can be purchased at dealer's price, pure, in which case it is cleaned to

export standards of 99.73% purity. When purchasing directly from growers, buyers are advised to take a dockage sample and deduct percent dockage from agreed price. Seed cleaning costs range from \$0.15 to \$0.25 per kilogram.

- **Stem only:** Refers to stalk of plant once it passes through a combine (straw). Any leaf material is usually crushed and blown through the combine, allowing the stem to be baled as a byproduct of seed harvesting (hemp).
- **Whole:** May be trimmed or sectioned, but not milled.

The cost and availability information was collected and prepared by Mr. Doug Elsasser, President of Parkland Botanicals (Togo, Sask). Mr. Elsasser has spent approximately seven years in the business of growing, wild harvesting, purchasing and processing medicinal herbs and botanicals.

Cytotoxicity Data

Cytotoxicity testing was carried out for each plant extract at a concentration of 1%. Water extracts were diluted to 1% and kept frozen until testing, while ethanol-extracted solids were reformulated to 1% in 50% aqueous glycerol. Testing was done by PBR Laboratories Inc. in Edmonton, Alberta.

Cytotoxicity, or *in-vitro* biological reactivity, was measured by manifestation of cellular degeneration and malformation of cell cultures which had been applied with a plant extract and incubated for 24 hours. Cytotoxicity data are presented in a table format at the end of this report.

The World Wide Web: the Internet as a source of information

It is non-disputable that the internet contains a voluminous and appreciable amount of valid botanical and herbal information. However, amongst the invaluable sources of information to be found, there is also much misinformation and unsubstantiated claims. When searching for information, it is therefore important to acquire data from reputable sites which preferably are referenced. Most university and government sites and those based on text are

reliable, however where there is product to be sold, one must be wary to discern fact from sales pitch. Among some of the best sites for botanical information:

✕ **Alberta Agriculture, Food & Rural Development**

(www.agr.gov.ab.ca/)

An excellent site with much information on alternative and herbal crops, as well as traditional grain crops. Includes research and conference proceedings.

✕ **Plants for a Future – A Resource & Information Centre for Edible and other useful plants.**

(<http://agora.scs.leeds.ac.uk/pfaf/index.html>)

A resource centre for rare and unusual plants including a database or over 7,000 species and leaflets on various plant uses: highly recommended!

✕ **Purdue University NewCROP – New Crop Resource Online Program.**

(www.hort.purdue.edu/newcrop/)

A remarkable source of information with an especially abundant amount of information on alternative crops. Includes a 'Guide to Medicinal and Aromatic Plants'.

✕ **Saskatchewan Agriculture & Food**

(www.agr.gov.sk.ca/)

Provides statistics, agronomic guides, reports and more on a variety crops grown in Saskatchewan including specialty crops.

✕ **Saskatchewan Herb & Spice Association**

(http://paridss.usask.ca/specialcrop/commodity/herb_spice/tour.html)

Information on over 30 herb and spice crops grown in Saskatchewan.

✕ **Agriculture and Agri-Food Canada – Medicinal Herb Research.**

(<http://res.agr.ca/long/pmrc/study/newcrops/ncweb.html>)

Comprised of 24 medicinal herbs including photographs and information on botany, properties and uses.

✕ **Texas A & M University Bioinformatic Working Group – Vascular Plant Image Gallery**

(www.csd.tamu.edu/FLORA/gallery.html)

Contains an enormous amount of great plant pictures: a great photographic resource!

✕ **USDA Plants Database**

(<http://plants.usda.gov/plants/index.html>)

Contains information on most plants from the US along with agronomic information and economic uses.

✕ **Southwest School of Botanical Medicine**

(<http://chili.rt66.com/hrbmoore/HOMEPAGE/>)

Great links to medicinal plant images, manuals, research, classic texts and other resources.

✕ **Virtual Foliage Home Page**

(www.wisc.edu/botany/virtual.html)

Contains over 2,000 excellent botanical pictures.

✕ **Internet Directory for Botany**

(www.botany.net/IDB/)

Provides over 3,000 links to botanic sites on the internet.

✕ **Health World MEDLINE Search**

(www.healthy.net/Library/Search/Medline.asp)

An excellent resource to access scientific papers and documentation.

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Alfalfa

Medicago sativa L.

Family: Fabaceae (Leguminosae)

Common names: Lucerne, Buffaloherb, Purple medick, Medicago

Scientific pseudonyms: none current

The forage legume with the greatest ability to assume many roles both within and outside of traditional grassland agriculture is alfalfa (Bouton 1996). Alfalfa has long been recognized for its excellent nutritive qualities and high digestibility, producing more protein per hectare than any other known crop. As such, its main historical and contemporary use has been as a forage crop, hay and silage and in dehydrated products. There is now increasing interest in its potential for nutraceutical and medicinal uses. As well, alfalfa has many other potential uses including nitrogen-fixation, pulp production, bioremediation and as an environmentally-friendly biofuel alternative.

Description & Habitat

Alfalfa is a deep-rooted, bushy perennial legume which grows to a height of 60-100 cm. The roots of its various varieties are of four general types: tap, branch, rhizomatous and creeping, all of which penetrate deeply 3-9 m into the soil from a woody crown that grows immediately above or below the ground surface (Looman 1983).

Its three-leaflet leaves are 1.3-3.8 cm long with smooth edges, slightly toothed at the tip (Goplen *et al.* 1987). Blue or purple (or sometimes yellow) flowers grow from June to August in clusters of 10 to 20 that develop into coiled pods containing up to 10 small seeds (465 seeds/g). Alfalfa is particularly well-adapted to deep, well-drained and near-neutral soils. Its optimum temperature for growth are 15-20°C during the daytime and 10-20°C at night with growth restricted above 30°C. It does not grow well on

strongly acidic or poorly drained soils, although it can tolerate extremely dry conditions.

Alfalfa forms a symbiotic relationship with the soil bacteria *Rhizobium meliloti*. This microorganism forms root nodules that symbiotically convert the unlimited atmospheric nitrogen supply into a form readily available to the plant. As alfalfa requires a large amount of nitrogen, this symbiotic nitrogen fixation will provide the plant with ~80% of its nitrogen requirement from the atmosphere, permitting growth on nitrogen-poor soils. As most Saskatchewan soil is deficient in this nutrient, it is generally recommended that alfalfa seed be inoculated with *Rhizobium* prior to seeding.

The rhizomatous and creeping-rooted types have a more protected crown and develop new roots more readily; creeping-rooted plants are more persistent under pasture management and general adverse conditions such as extreme cold and trampling by livestock (Goplen *et al.* 1987).

Cultivation & History

Alfalfa has been cultivated for thousands of years and can be found growing domestically or wild from subtropical to subarctic latitudes. It is thought to be native to southwestern Asia with Iran as its probable geographic centre of origin. The oldest historical records reveal that alfalfa was cultivated and prized as a highly nutritious animal feed in Persia and Turkey more than 3 thousand years ago (Goplen *et al.* 1987). Alfalfa made its introduction to Canada quite recently in 1871, although the particular strain was not very hardy on the prairies and growth remained restricted to eastern Canada. Successful cultivation of alfalfa in western Canada commenced following the introduction of a hardier strain by a German farmer.

Several licensed cultivars are available of which few are adapted to all regions (Goplen *et al.* 1987). Between 1962 and 1992, 440 publicly and privately developed cultivars were approved for certified seed production in the US (NPDC). In Saskatchewan, resistance to extreme climate is particularly necessary to survive winterkill. Algonquin and Beaver are the most common types grown; both have very good cold tolerance, are resistant to bacterial wilt and have medium recovery after cutting (Goplen *et al.* 1987).

Today, alfalfa is grown in every Canadian province although Saskatchewan currently accounts for approximately 40% of Canadian production. Saskatchewan currently produces in excess of 300,000 tonnes annually from a land base of approximately 165,000 acres (Tremblay 1997). Total Canadian processed alfalfa production in 1994-95 was estimated at a record 832,000 metric tonnes; approximately 85% of which was exported.

Markets for processed alfalfa have predominantly been in the Pacific Rim countries of Japan, Korea and Taiwan where a growing livestock industry, particularly dairy, and a shortage of land to grow forage crops has led to large quantities of forage imports (Tremblay 1997). The vast majority of production continues to be dehydrated and suncured alfalfa pellets, although quantities of regular and small cubes continues to slowly increase. One small operation is involved in compressed baled hay for export (Tremblay 1997). Saskatchewan accounts for over 50% of the Canadian acreage for production of alfalfa seed, with 10 million pounds produced in 1995 (SAF-AS). Much of this production is exported to the United States.

Alfalfa is usually a bit slow to establish in its first year, but is very vigorous from its second year on, producing a huge bulk of materials that can be cut down two or three times during a season (PFAF). Highest yields are obtained in moisture-rich area with a soil pH of 6.5 or above. Alfalfa leafcutting bees (*Megachile rotundata*) are necessary for optimum seed set of alfalfa. Many alfalfa seed producers keep their own leafcutter bees which creates a second enterprise in years when a surplus of leafcutting bee larvae are produced (SAF-AS). There is a demand for Canadian leafcutting bee larva in the US where disease has limited their production.

For complete agronomic instruction, please refer to the Agriculture Canada publication "Growing and managing alfalfa in Canada" by Goplen et al. (1987) or the SAF publication "Alfalfa Production for the Dehy Industry" by M. Tremblay (1997). Both are available at any Rural Extension office of Saskatchewan Agriculture and Food (the latter is also available on the SAF website).

Products & Uses

• Forage and Hay Crop

Highly valued as a legume forage, alfalfa has been heralded as having the highest feeding value of all commonly grown hay crops (Duke 1985). Alfalfa is palatable to all livestock and is the best legume crop for irrigated land, having also produced excellently on dry land (Looman 1983). Alfalfa supplementation in feed has been found to increase the weight and milk production of cattle and also produced weight gain in fowl (Hamon et al. 1985).

Its digestibility when fed alone is not high, seldom over 55% on a dry-matter basis, but its high protein and mineral contents make it an excellent supplementary feed to balance rations (Looman 1983). When mixed with native hays, it increases their digestibility and apparent palatability; when grown in mixtures with grasses, it lengthens the life of the stand and the mixture outyields either grass or alfalfa grown alone.

• Dehydrated Products

The high nutritional quality of alfalfa is best retained when it is processed into dehydrated products including cubes, pellets and leaf protein concentrate (Goplen et al. 1987). Dehydrated alfalfa is used as either an excellent protein and fibre supplement or the sole dietary ration for cattle, horses and other small pet animals such as gerbils and rabbits.

In Saskatchewan there are at least a half dozen alfalfa dehydrating plants of which the Tisdale Alfalfa Dehy. Ltd. plant represents one of the most advanced. It has been in operation since 1969. In the 1999 operating season of June to October, approximately 86,000 tonnes of alfalfa was processed into cubes and pellets, most of which will be exported for the feed industry (Dale Davidson, personal communication).

Typical nutrient specifications for major alfalfa products produced in Saskatchewan are as follows (Tremblay 1997):

Dehydrated Pellets

- 17% crude protein
- 165 mg/kg carotene
- 25% crude fibre
- 10% moisture

Suncured Alfalfa Pellets

- 25% crude protein
- 28% crude fibre
- 10% moisture

Alfalfa Cubes

- 32% crude fibre
- 12% moisture

• **Pulp Production**

Another potential use for alfalfa is as a source of pulp for paper manufacturing (Bouton 1996). In 1993, researchers in Sweden investigated the possibilities of using high yielding grasses and alfalfa instead of trees for pulp and paper production (Berggren 1993). The report was optimistic about the future of agro-fibre production as the fibre yield per unit of land of alfalfa was much higher than that of traditional birch trees (Bouton 1996). Alfalfa has prior use in manufacturing paper (Duke 1985) and seems to be a viable alternative.

• **Fuel and Bioremediation**

Alfalfa has been grown as a cover crop to reduce soil erosion, being one of the most important soil-improving crops when used in rotation; its deeply penetrating taproots open up the subsoil, and when the roots decay numerous channels are formed that improve the circulation of air the percolation of water (Goplen *et al.* 1987). It often increases yields of succeeding crops such as potatoes, rice, cucumber, lettuce, tomatoes (increased by 10 MT/ha), corn, apples and oranges (Duke 1985).

Alfalfa is also being investigated as a bioremediation system for removal of harmful nitrates in the treatment of nitrate-contaminated soil (Bouton 1996). For nitrate bioremediation to be successful, it was important to develop an alfalfa which possessed a more extensive rooting pattern yet was ineffective in establishing the nodulation and nitrogen fixation process in order to obtain its nitrogen exclusively from the soil. When developed, it was found to remove 140 and 700 kg/ha more nitrates than reed canarygrass (*Phalaris arundinacea* L.) and switchgrass (*Panicum virgatum* L.).

The United States Department of Agriculture and the University of Minnesota are cooperatively investigating the potential use of alfalfa as a fuel for generating electricity. This project estimates a potential for converting

700,000 tonnes of alfalfa per year into enough electricity to power a city with a population of 50,000. In the proposed process, the alfalfa stems would be separated and used to create gas for fueling a 75-megawatt power plant while the leaves would be processed into dehydrated animal feed.

• **Cosmetic Applications**

Alfalfa is used in facial steams and as a mild exfoliant in oils, soaps, creams, lotions and hair rinses (D'Amelio 1999). Due to its high mineral content, alfalfa is also listed as a good component for bath gels and oils while its very rich protein content makes it a good source of vegetal protein for hair conditioners.

• **Food Uses**

The leaves and young shoots of alfalfa can be eaten raw or cooked, or dried for later use. Beginning in the 1970's, alfalfa seed sprouts found a major use in human diets in salads and sandwiches (Bouton 1996). It is a highly nutritious food in moderation; very rich in vitamins and a good source of protein. Seeds can also be ground into a powder and mixed with cereal flours to make nutritionally improved bread (PFAF). Alfalfa extract has also been similarly used in a variety of food products including baked goods, beverages, candy, frozen desserts, gelatins, liqueurs, meats, produce and puddings (Duke 1985).

Alfalfa is available in a powdered form to be used either orally in one tablespoon oral doses or as a tea or tablet form in doses of 600-1800 mg taken three times daily (Hamon *et al.* 1985).

• **Nutraceutical and Medicinal Uses**

As detailed by Sen *et al.* (1998), while the saponin content of alfalfa has always been considered as deleterious by animal scientists, a number of recent studies have shown some beneficial effects. A significant reduction in the serum cholesterol level was observed when human volunteers consumed alfalfa seeds in a fruit juice suspension at meal time for three weeks. Alfalfa saponins possess the property of lowering the plasma cholesterol concentration by forming insoluble complexes, and this may be considered as an important factor in human diets to reduce the risk of heart disease.

Alfalfa leaves are traditionally used as a tea to treat diabetes in South Africa (Lust 1986). Recent study has confirmed the antihyperglycaemic, insulin-releasing and

insulin-like activity of alfalfa (Gray *et al.* 1997) and researchers consider alfalfa to represent a possible dietary adjunct for the treatment of diabetes and a potential source for discovery of new agents with oral antihyperglycaemic activity.

Ingestible uses of alfalfa seed extracts must take account of the content of the amino acid canavanine present in seeds. Some processing (and patented) methods have been developed to remove this component.

• **Assorted Others**

Alfalfa is gaining notoriety in the biotechnology industry as a good candidate plant for engineering with unique genes (i.e. the field of transgenics); it is easily grown and regenerated in cell culture, and is also receptive to transformation vectors (Austin *et al.* 1993). These researchers concluded that this technology could be used for inserting genes and extracting products for other value added traits in alfalfa.

Alfalfa extract has antibacterial activity against gram-positive bacteria and its seeds yield 8.5-11% of a drying oil suitable for making paints and varnish (Duke 1985).

The abundance of cheap alfalfa has allowed it to be used in manufacturing animal litter products. Several patents exist for such application.

Chemical Characteristics

Constituents

Seed content (Duke 1985):

- Water 11.7%
- Protein 33.2%
- Fat 10.6%
- Fibre 8.1%
- Minerals 4.4%
- N-free extract 32.0%

Carbohydrates include: arabinose, fructose, sucrose, xylose. Additional vitamins include: B₁, B₆, B₁₂, C, E and K.

Leaves components; fresh weight/100g (Duke 1985):

- Water 82.7%
- Calories 52
- Protein 6.0 g

- Fat 0.4 g
- Carbohydrate 9.5 g
- Fibre 3.1 g
- Ash 1.4 g
- Calcium 12 mg
- Phosphorus 51 mg
- Iron 5.4 mg
- Vitamin A 3410 IU
- Vitamin C 162 mg
- Thiamine 0.13 mg
- Riboflavin 0.14 mg
- Niacin 0.5 mg

Content of various alfalfa preparations per 100 g (Duke 1985):

	<i>green forage</i>	<i>alfalfa whole meal</i>	<i>leaf meal</i>
moisture	80.0%	7.5%	8.0%
protein	5.2 g	16.0 g	20.4 g
fat	0.9 g	2.5 g	2.6 g
fibre	3.5 g	27.3 g	17.1 g
ash	2.4 g	9.1 g	11.5 g

Chemical constituents of alfalfa (Newall *et al.* 1996):

- **Acids:** Lauric acid, maleic acid, malic acid, malonic acid, myristic acid, oxalic acid, palmitic acid, quinic acid
- **Alkaloids:** Pyrrolidine-type (i.e. stachydrine, homostachydrine; pyridine-type (i.e. trigonelline) in the seeds only
- **Amino acids:** Arginine, asparagine (high concentration in seeds), cystine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine. The non-protein amino acid, canavanine, is in high concentration in the seed (8.33-13.6 mg/kg) and low in the aerals.
- **Coumarins:** Medicagol
- **Isoflavonoids:** Coumestrol, biochanin A, daidzein, formononetin, genistein
- **Saponins:** (2-3%) Medicagenic acid, soyasapogenols A-F, hederagenin
- **Steroids:** Campesterol, cycloartenol, beta-sitosterol (major component), alpha-spinasterol, stigmasterol
- **Others:** Carbohydrates, pectin, pigments

Composition of alfalfa meal fractions (Duke 1983):

	Triglyceride	Phospholipid
Linoleic acid	16.9%	14.7%
Linolenic acid	32.2%	35.2%
Oleic acid	31.0%	36.8%
Saturated fats	19.9%	13.3%

Toxicology

Canavanine is known to be toxic to all animal species because of its structural similarity to arginine. In alfalfa, the highest concentration of canavanine is in the seeds (8.33-13.6 mg/kg), although considerably lower in the aerials (Newall *et al.* 1996). Both alfalfa seed and herb have been reported to induce a systemic lupus erythematosus-like syndrome attributable to canavanine's activity, but mostly in patients where the disease had become dormant (Foster *et al.* 1990).

Saponins are sometimes alleged to be toxic materials, potentially irritating mucous membranes and destroying red blood by hemolysis (Lewis *et al.* 1977). Alfalfa seed saponins lack medicagenic acid and as a result they do not hemolyze red blood cells (Jurzysta 1973).

Excessive ingestion of alfalfa should be avoided in view of such pharmacologically active constituents (including canavanine, coumarins and isoflavones) which may give rise to unwanted effects if taken in excess (Newall *et al.* 1996). Large quantities can affect liver function and cause photosensitization (Bown 1995). However, saponins are poorly absorbed by the human body and so most pass through without harm (PFAF). Alfalfa has tested negative for mutagenicity (Malinow *et al.* 1982), while dietary studies in rats and monkeys using alfalfa top saponins showed no evidence of toxicity and serum lipid levels were actually lowered (Malinow *et al.* 1982; Malinow *et al.* 1981; Rene *et al.* 1981).

Alfalfa contains two phytoestrogenic compounds, coumestrol and coumestan. Alfalfa tablets available for dietary supplementation contain 20-190 ppm of these substances. Such a level of intake, in conjunction with other sources of estrogen such as birth control pills and estrogen replacement therapy, may be potentially harmful (Cheeke *et al.* 1985).

In the US, the FDA has listed alfalfa "Generally Regarded As Safe" while in Europe, alfalfa is listed by the Council of Europe as a source of natural food flavouring such that it can be added to foodstuffs in small quantities, with a possible limitation of an active principle (as yet unspecified) in the final product (Newall *et al.* 1996).

Extracts

Water extraction of dried, ground herb material produces a clear, slightly viscous dark yellow-green extract with an orange tinge and an extractive yield of 34.4%. The extract was filtered by cheesecloth and had a strong iced tea/sweet hay aroma. Water-extracted solids consist of a dark-red coloured, iridescent solid with only a very slight odour. The residual extracted material, originally a very fine green powder, dried to form a very clumpy, hard solid.

Ethanol extraction produced an easily filtered dark green extract with an extractive yield of 20.7%. Residual extraction material remained a very fine powder, although light yellow in colour. Extract solids are a dark ruby coloured, crystalline solid, much resembling the water-extracted solids but with a stronger, sweeter smell.

Patents

Alfalfa has many patents; the US PTO lists 89 and CIPO 186, most of which involve agronomic techniques or genetic engineering and are too numerous to list here. Many patents also list alfalfa as one of many possible components: if interested in a particular faculty, it is advised to revisit the site for specifics. The following select patents reflect the variety of uses and global utilization of this plant (reminder; this is not a comprehensive list):

- ❖ 5884584 (99/03/23) Feldman P.
Animal litter; 5-60% used in a mixture with pine and poplar.
- ❖ 09909810 WO (99/03/04) Hoard *et al.* US
Alfalfa plants having measurable endogenous tannin levels for use as alfalfa forage for improved ruminant health and nutrition and methods of identifying and breeding tannin-expressing alfalfa plants.
- ❖ 05853576 (98/12/29) Kapulnik Y. *et al.*
US

Phytorecovery of metals using seedlings

- ❖ 10245500 JP (98/09/14) Belcour et al.
JAPAN

Colourant precursor derived from plant of Genus Medicago, its production and its use for production of colourant; derived from 1,4-naphthoquinone

- ❖ 05770223 (98/06/23) Bonte F. et al.
FRANCE

Method of treatment for combatting the effects of aging on the condition of skin and hair; use of Medicago saponins for the preparation of cosmetic of pharmaceutical compositions to promote renewal of epidermis, stimulate hair regrowth or delay hair loss.

- ❖ 05747297 (98/05/05) Clark A. US
Industrial pharmaceutical and cosmetic applications for cultured plant cell gums; for use in paper, adhesive, oil and gas, ink, textiles etc..

- ❖ 00575496/EPB1 (97/08/27) Bonte F. et al.
FRANCE

Cosmetic or pharmaceutical, especially pharmacological, composition containing oxyacanthine, in particular for stimulating hair growth or retarding hair loss.

- ❖ 5447720 (95/09/05) Fadulu S.O.
Composition and method for treatment of hemoglobinopathies; hexane-extraction of base treated alfalfa extract alleviates sickle cell anemia's clinical manifestations.

- ❖ 00558509/EP B1 or CA2106097 (95/03/15) Bonte F. et al. FRANCE

Use of Medicago saponins for the preparation of cosmetic or pharmaceutical compositions, dermatological compositions in particular, helping renew the epidermis, stimulating regrowth of hair or delaying hair loss.

- ❖ 06040884 JP (94/02/15) Kawasaki et al.
JAPAN

Whitening cosmetic; a cosmetic having high skin whitening effect, also excellent in safety and stability, containing alfalfa extract.

- ❖ 5277910 (94/01/11) Hidvegi M.
Process for preparation of a pharmaceutical composition selectively lowering the blood lipid level. Extraction of any part of the plant with water at $>40^{\circ}\text{C}$, $\text{pH}<8$; composition contains neither canavanine nor coumestrol.

- ❖ 5116545 & 5225447 (93/07/06) Weinheimer A.J.

Composition and method for the treatment of sickle-cell anemia; free acids from alfalfa show control.

- ❖ 05017562 (91/05/21) Holmes T.J. et al.
US

Crystalline saponin-containing complex.

- ❖ 01247065 (89/10/02) Fujita et al. JAPAN
Production of drink; to improve emulsification and stability of drink.

- ❖ 04594412 (86/06/10) Kitagawa I. JAPAN
Method for isolating soyasaponins.

- ❖ CA1203167 (86/04/15) Danila M.
ROMANIA
Drug for the treatment of the neoplastic disease.

- ❖ 60214866 JP (85/10/28) Nomura Y.
Health tea produced from alfalfa as raw material and production thereof; a health drink rich in nutrient.

- ❖ 34868 (85/05/28) Bartha F. et al.
HUNGARY
1-triacontanol or 1-triacontanol concentration of Medicago sativa leaves.

- ❖ 04318906 (82/03/09) Llopart J-P.
FRANCE
Medicinal composition for external use for treating wounds; a liquid Medicago composition with a variety of tinctures and essential oils.

A few additional patents describe various other animal litter preparations (i.e. straw, alfalfa and sunflower hulls); as well as a 1977 patent for preparation of soluble, edible protein from leafy green crops.

Cost & Availability

Plant parts: seeds only, blooming aerals (baled)

Sask. Availability: This herb is extremely common in cattle-producing regions. Both conventionally grown and certified organic seed and forage is sold.

Sask. Prices:

Conventional seed

Grower direct, bin-run: \$1.90-\$2.40/kg
Dealer's price, clean and bagged: \$2.75-\$3.75/kg

Conventional forage

Grower direct, baled: \$60-\$80/tonne

Certified Organic seed

Grower direct, bin-run: \$3.00-\$4.00/kg

Dealer's Price, clean and bagged: \$4.25-

\$5.50/kg

Certified Organic blooming aerials (baled)

Grower direct, 90% pure: \$95.00-\$140/tonne.

Potential suppliers: Conventional buyers can consult Saskatchewan Agriculture & Food's website Re: special crops and forages. The OPIS (306) 933-5400 sells trading information to buyers and sellers of certified organic crops. The *Western Producer Classified Section* is also good trading resource.

Recommended Resources:

M Duke, James A. 1983. *Medicago sativa* Handbook of Energy Crops (unpublished). NewCROP: New Crop Resource Online Program. Centre for New Crops and Plant Products. Purdue University.

(<http://www.hort.purdue.edu/newcrop/>)

- a veritable wealth of information on the chemistry, uses, cultivation, harvesting, yields and economics, folk medicine, toxicology (etc.) of alfalfa

M Goplen B.P. et al. 1987. *Growing and managing alfalfa in Canada*. Publication 1705/E. Agriculture Canada.

- although mainly intended as a production guide (weed control, fertilizers, pests), this document also contains very interesting information about alfalfa history, uses and characteristics

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(www.csd1.tamu.edu/FLORA/)

Astragalus

***Astragalus membranaceus* (Fisch.) Bunge**

Family: Fabaceae (Leguminosae)

Common names: Chinese milkvetch, Milkvetch root, Huang qi, Huang-Chi, Membranous milkvetch

Scientific pseudonyms: *Astragalus americanus* (Hooker) Jones; *Astragalus frigidus* (L.) Gray; *Phaca americana* (Hook.) Rydb., *Astragalus membranaceus* Bge. var. *mongolicus* (Bge).

While astragalus has been utilized in eastern medicine for thousands of years, the resurgence of botanical medicinals and alternative therapy in Western society has brought much attention to this Asian plant. *Astragalus* possesses significant immunostimulatory action and has been found to overcome the toxicity of cancer chemotherapy to the hematopoietic system. It has been identified by several eminent herbalists and pharmacognosists as worthy of North American production and there is indeed increasing interest from the nutraceutical industry in acquiring local suppliers.

Description & Habitat

Astragalus membranaceus is an introduced perennial herbaceous member of the very large milkvetch group. *Astragalus* grows from a woody base to a form a multi-branched herb with a height of 50-100 cm tall and alternate, pinnately-compound leaves that usually number 8-12 leaflet pairs. It also produces yellowing stalks of flowers that yield stalked shiny pods containing seed. *Astragalus* has an angular, glabrous stem which and a cylindrical, branched root 30-90 cm long and 1-3.5 cm in diameter. It is yellowish-brown in colour and strongly fibrous.

Wild *Astragalus membranaceus* grows along forest edges, thin open woods and grassland (Gunner 1998). It is also cultivated on a large

scale in China, as well as on several Saskatchewan farms.

Native astragalus species are of considerable importance on the Prairie provinces, occurring on grasslands where they are accessible to grazing livestock (Looman 1983). Although there are 29 species listed in Budd's Flora of the Canadian Prairie provinces, there are nearly 400 *Astragalus* species growing predominantly in the western region of North America, several of which are classified as noxious weeds.

It has been suggested that *Astragalus membranaceus* may be the same species as the locally abundant *Astragalus americanus*, which is reported to have the same chemical markers via chromatography (HLTLC). *Astragalus americanus* is a close relative, if not simply a regional variant, of *Astragalus membranaceus* (Moore, SSBM). *Astragalus americanus* is found on streambanks and moist open woods along the southern fringe of the boreal forest and west of Great Bear Lake into interior Alaska. There appear to be no endeavours to investigate any similarities.

Cultivation & History

Astragalus membranaceus is native to northern China and the elevated regions of the Chinese provinces Yunnan and Sichuan (Leung *et al.* 1996). Although astragalus root has been utilized as a traditional medicine in Asia for thousands of years, its use as a herbal is of relatively new status in North America. Some native species do have historical medicinal use: *Astragalus americanus* was used by the Cree who chewed the roots and swallowed the juice if they had stomach aches, cramps or stomach flu (Johnson *et al.* 1995). However, the local value of this genus remains as a forage plant.

With its rapidly mounting scientific literature, *Astragalus membranaceus* is quickly gaining notoriety in North America. In a 1998 study of BC nutraceutical manufacturers, astragalus was listed as a medicinal plant that there would be interest in sourcing from growers and wildcrafters in the future (Wills *et al.* 1999). *Astragalus* has also been identified by several eminent herbalists and pharmacognosists as being worth of North American production (Gunner 1998).

Most astragalus sold in the world originates from China, although the capacity for North

American production exists even if based solely on the number of members of the genus occurring naturally (Foster *et al.* 1992). The Chinese generally consider the quality of cultivated astragalus roots to be superior to wild roots (Gunner 1998). Current North American market volumes continue to be very small, but are expected to increase.

Astragalus membranaceus has been successfully cultivated across the prairie provinces including Saskatchewan. Plants are hardy to at least -15°C (Bown 1995) and prefer sandy, well-drained alkaline soil. Stored seeds, and perhaps also fresh seed, should be pre-soaked for 24 hours in hot water before sowing (PFAF).

Germination time is generally 5-7 days for pre-treated seeds and 2-3 weeks for untreated seeds (Gunner 1998). As soon as seedling as large enough to handle, they can be sown into individual pots and grown in a greenhouse for their first winter, then planted out into their permanent positions in late spring or early summer, after the last expected frosts (PFAF). Collection of the root for medicinal use occurs following 4-7 years of growth and is collected in the springtime. As with most root collection, harvesting can be an arduous and time-consuming process.

Much agronomic research has been conducted in Japan where astragalus undergoes vigorous cultivation. Recently investigated by Shibata *et al.* (1996b) were the effects of various soil plowing techniques (by trencher, backhoe, tractor or no plowing) on the growth and chemical composition of astragalus. In trenched plots, the taproot reached a length of 80 cm in the first year of growth, with a small number of lateral roots. In the other three plots, taproot growth was limited to 40 cm with frequent lateral roots. This is thought due to higher root penetration resistance (soil hardness) than is acquired by trenching.

Chemical differences resulting from differing plowing conditions were also discovered. The taproot produced in the trencher plot contained a large amount of astragalosides with a small amount of isoflavonoids.

It was concluded that for optimum growth of astragalus (development of a long taproot with little lateral development) with desirable chemical characteristics, it should be grown in a field with good drainage, low water level and low

penetration resistance (a trait best obtained by trenching). Astragalus has also been found to grow well and have a high isoflavonoid content on sandy and brown soils (Shibata *et al.* 1996a).

Products & Uses

• Medicinal Uses

Astragalus is a medicinal plant frequently used as a traditional medicine in China, Japan, Korea and southeast Asia (He *et al.* 1991). Much of the voluminous recent research examining the therapeutic effects of this herb has accordingly been conducted in Asia, although its study in North American institutions is steadily augmenting. Many immunostimulant and beneficial medicinal effects, especially in regards to cancer therapy, have been reported. Results of some of this research are as listed below, although this represents but a select few references of very many:

- Astragalus has been found to overcome the toxicity of cancer chemotherapy in the hematopoietic system; it has both immunostimulant and cytoprotective activity (CMU 1997).
- The severity of induced liver fibrosis in rats was significantly reduced with astragalus treatment (Hong *et al.* 1997).
- Astragalus root components have significant antioxidative properties superior to butyl hydroxytoluene and alpha-tocopherol (Shirataki *et al.* 1997).
- The crude extract has shown significant antiviral and immunostimulant activities (He *et al.* 1991); as well as antimicrobial activity (Liu 1997).
- Astragalus extract showed a significant stimulatory effect in human sperm motility; the only herb of 18 tested to possibly find application in the treatment of male infertility (Hong *et al.* 1992).
- Administration of astragalus extract produced an enhanced immune response (Zhao *et al.* 1990) and is capable of reversing the immunosuppressive effects of tumours (Rittenhouse *et al.* 1991).

- Heart cells infected with Cocksackie virus and treated with astragalus extract maintained more regular rhythms, beating frequency and beating percentage and suffered less cellular damage from the viral infection; astragalus was over 85% effective in preventing heart damage from virus infection (Yang *et al.* 1990).
- Oral administration of an ethanol extract has been demonstrated to exert hepatoprotective effects (Zhang *et al.* 1990).

Astragalus is a component (either in formula or alone) in many cold and flu/immune boosting products (Wills *et al.* 1999). Astragalus root can be purchased locally in a variety of encapsulated forms.

• **Cosmetic Applications**

Due to its reported ability to dilate the blood vessel and improve circulation in the skin, astragalus has been used in hair tonics for its vasodilating properties (D'Amelio 1999). Astragalus root has also been used in antiperspirant formulations (Shirataki *et al.* 1997).

Chemical Characteristics

Constituents

Root constituents (Zheng *et al.* 1998):

- saponin 5.81%
- astragaloside (I-VII) 0.14%
- total polysaccharide 22.97%
 - acidic 8.29%
 - soluble 14.88%
- betaine, astrapterocarpan, astraisoflavan, fructose, glucose, formononetin, gaba, isoastragaloside I, II, IV, soyasaponin I, isoliquiritigenin, beta-sitosterol, choline, linoleic acid, linolenic acid
- Isoflavones include genistein, daidzein, afrormosin, calycosin and odoratin; all of which demonstrate antioxidative activities (Shirataki *et al.* 1997)

Mineral content in root (Duke 1983):

- calcium 1,700 ppm
- copper 1 ppm
- iron 460 ppm
- magnesium 1,860 ppm
- manganese 29 ppm

- potassium 10,000 ppm
- sodium 56 ppm
- zinc 16 ppm

Toxicology

No specific information regarding astragalus could be located. It is reported that many members of the Astragalus genus contain toxic glycosides and that a number of species can also accumulate toxic levels of selenium when grown in soils that are relatively rich in that element (PFAF).

Extracts

Dried astragalus root, beige in colour with a powdery cortex, was ground to a fine fibrous powder for extraction. Extraction by water yielded a highly viscous extract with an oatmeal-like texture and a very spicy, disagreeable astringent smell. Filtration was an arduous procedure and was accomplished by vigorous cheesecloth filtrations. Residual extracted material dried to a clumpy, gummy solid while dried extract solids produced a light, yellow crystalline solid with a bubbly texture and a slight sweet smell. An extractive yield of 37.9% was obtained.

Ethanol extraction produced a clear, vivid deep yellow liquid which looked similar to apple juice. Residual material much resembled the original; a beige, fibrous powder. Dried extract solids has a deep, sweet and syrupy odour which smell remarkably like peanut brittle. The solids are a golden orange crystalline solid. An extractive yield of 10% was obtained.

Patents

There are many patents for Astragalus products; many for cosmetic and immunostimulant properties and mostly centered in Asia.

♦ 1102558 (99/05/17) Wu *et al.* CHINA
Cigarette toxicity reducing additive.

♦ CA2204210 (98/11/01) Chang T.S.
TAIWAN

Herb composition and an herbal plaster made from the same.

♦ 2226572 (97/01/30) Yang Y.F.
AUSTRALIA

Herbal composition for hepatic disorders.

❖ 2285578 (95/07/19) Leilani L. UK
Beverages containing added guaranine.

❖ 1100650 (95/03/29) Zheng et al. CHINA
Preparation of heme capsule as iron supplement.

❖ 1092959 (94/10/05) Zhang T. CHINA
Additive for cigarette.

❖ CA2142270 (94/03/03) Verbiscar A.J. US
Astragalus polysaccharide immunomodulators.

❖ 04270213 JP (92/09/25) Agawa et al.
JAPAN
Bathing agent composition; Astragalus membranaceus-containing bath agent with excellent warming effect and heat-insulating to improve blood circulation.

❖ 04169536 JP (92/06/17) Yamahara et al.
JAPAN
Therapeutic agent for osteoporosis.

❖ 00441278/EP A1 or CA2035948 (91/08/14)
Bombardelli et al. ITALY
Polysaccharides with immunomodulating properties from Astragalus membranaceus and pharmaceutical compositions containing them; to aid in radiation antineoplastic therapy, chemotherapy and in prevention of bacterial and viral infections.

❖ 1047296 (90/11/28) Chu D. CHINA
Immunostimulant containing interleukin-2 and substance F3 from Astragalus membranaceus as activity enhancer.

❖ 04944946 (90/07/31) Liu Y. US
Pharmaceutical composition for inhibiting viruses and increasing immune function.

❖ 01197422 JP (89/08/09) Fuji S. JAPAN
Hair tonic: promotes nourishing growth and development of hair and prevents fall-off by improving blood flow.

❖ 01179662 JP (89/07/17) Takizawa I.
JAPAN
Preparation of Chinese 'Miso'

❖ 4843067 (89/06/27) Liu Y. US
Polysaccharide containing pharmaceutical composition for increasing the immune function.

❖ 01061411 JP (89/03/08) Fuji S. JAPAN
Hair restoration agent.

❖ 8712791 (87/01/21) Uchida Y. JAPAN
Preparation of medicinal saponins from Astragalus membranaceus roots.

❖ 61263905 JP (86/11/21) Fukushima et al.
JAPAN
Cosmetic; improved skin with a beautifying and whitening humectant effect.

❖ 60025933 JP (85/02/08) Okuda et al.
JAPAN
Agent for mitigating symptoms of cancer; inhibits the fat decomposition accelerating action of cancer toxin and promotes lipid metabolism and appetite of cancer.

Cost & Availability

Plant part: root

Sask. Availability: *Astragalus membranaceus* is grown by at least a dozen Saskatchewan medicinal herb growers. It takes between four and seven years to grow a mature root.

Sask. Prices:

Conventional

Grower Direct, whole or milled: \$11.00/kg
Dealer's Price, whole or milled: \$13.00-\$15.00/kg

Cert. Organic

Grower Direct, whole or milled: \$16.50/kg
Dealer's Price, whole or milled: \$17.00-\$20.00/kg

Availability outside Sask.: This herb is cultivated in B.C. and Ontario on a larger scale.

Potential Suppliers:

- ♦ Mid-Northern Growers, Moose Jaw Sask. (306) 693-2272
- ♦ V.E. Gardens, Burford Ontario (519) 449-1422

Bearberry

Arctostaphylos uva-ursi (L.) Spreng.

Family: Ericaceae

Common names: Uva-ursi, Kinnikinnik, Ptarmigan berry leaves, Bear's grape, Mountain box (Engl.)

Scientific pseudonyms: *Arbutus uva-ursi* L., *Arctostaphylos officinalis*, *Uva-ursi procumbens*, *Uva-ursi uva-ursi* L. (Britt.)

Although one of the most ubiquitous herbs in Saskatchewan (Bart et al. 1996), bearberry locally serves little purpose other than as wildlife forage and as an occasional ornamental, despite its presence as an active ingredient in excess of 150 products sold in Canada. Most of these products are imported from Europe, where bearberry is a valuable commercial plant. It has official classification as a phytomedicine in France and in Russia, its use as a medicinal has warranted extensive research and efforts at cultivation and harvest. The commercial importance of bearberry is based on its astringent properties and beneficial effects in nephritis and other diseases of the urinary system. It would appear that bearberry is a tremendously underutilized natural resource.

Description & Habitat

Bearberry is a prostrate native evergreen shrub, reaching a mere 7.5-10 cm off the ground (Johnson *et al.* 1995). In the British Isles, however, it has been reported to grow as tall as 1 m when conditions are suitable (Chiej 1988).

It is a conspicuously low-lying plant, with long rooting glabrous branches that form a dense mat. In Montana, bearberry roots have been found to extend to a depth of 91 cm on one site and 183 cm on a drier site with the same soil type (Nimlos *et al.* 1968) while in two jackpine stands in central Alberta, roots extended 110-135 cm (Strong *et al.* 1986). The persistent leaves, which are borne on very short petioles, are leathery, obovate and obtuse; they are dark

green and glossy on the upper surface but paler underneath (Chiej 1988). The leaves may also become slightly reddish. Pink or white bell- or urn-shaped flowers appear in May or June in drooping terminal clusters in the axils of the fleshy bracts. The edible 6 mm fruit is a shiny red, globose drupe containing five single-seeded nutlets which develop by September (Bunney 1992). Its flavour has been described as everywhere from sharp (Chiej 1988), insipid (PFAF), to mealy and tasteless (Johnson *et al.* 1995).

The overall energy and protein values of bearberry browse are considered low, as are its palatability and graze potential (NPDC). However, since bearberry's low-quality fruit spoils slowly, it lasts through winter and is available when other fruits are gone (Stiles 1980). The fruits of bearberry are therefore an important winter food supply and are eaten by songbirds, gamebirds, deer, elk and small mammals and, quite appropriately, bears (hence its common name and its generic name; from the Greek words *arktos* = a bear and *staphyle* = grape).

Seeds need to be scarified and stratified prior to germination to reduce the seed coat and break embryo dormancy. Bearberry produces an average of 40,900 cleaned seeds per pound (NPDC).

Bearberry grows preferentially on sandy and well-drained soil and is common in woodlands, rocky hills and eroded slopes throughout the prairie provinces (Johnson *et al.* 1995). It is a circumpolar species, present throughout North America, North and Central Europe and Asia. It grows in acid soil on moors, screes and mountain scrub in northern parts of Britain and Ireland and on limestone in the European Alps, especially common in the Scottish Highlands (Bunney 1992).

Cultivation & History

Bearberry is cultivated for use as a medicinal plant and as an ornamental species, for which several varieties have been developed. It is a shade-tolerant plant, although will tend to produce less fruit when grown in shade (Huxley 1992). Bearberry is one of the first plants to colonize bare and rocky ground and burnt over areas (Arnberger 1968), and is often an indicator of poor soils in the wild (Craighead *et al.* 1963). Its soil pH range is 5.5-8.

Despite being one of the most common species in Saskatchewan, there appear to be no local efforts at cultivation (Barl *et al.* 1996). However, this plant has long been collected for medicinal uses, especially for kidney and bladder problems, in both North America and Europe. The parts used medicinally are usually gathered in autumn. Only green leaves should be selected and dried by exposure to gentle heat (Grieve 1992).

In Europe, the drug comes entirely from wild plants growing in Spain, Italy, the Balkans and Russia (Bissett 1994). Varieties such as Czechoslovak cv. *Arbuta* have also been developed which do not flower but contain 11-14% and 7.4-13% arbutin in the leaves and wood, respectively (Musil *et al.* 1988). Bearberry can be propagated from seeds, softwood cuttings or pre-rooted stem cuttings. Stem or softwood cuttings are the best method of establishment (Crane 1991) and should be harvested in late summer. Rooted stem cuttings are most successful when harvested during the dormant season (NPDC), although bare root cuttings are rarely effective and difficult to root.

Bearberry can also be successfully propagated in a greenhouse with commercially available seed, as best described in the Plants for a Future database: dried seeds are pre-soaked in boiling water for 10-20 seconds (or briefly heated by flame) and then stratified at 2-5°C for two months. Seeds will usually germinate following two to three months at 15°C. Once plants are large enough to be handled, the seedlings can be separated into individual pots and grown in a cold frame or greenhouse for their first winter at least.

Much research on the processing of bearberry has been conducted by V.F. Mukhina of the *Lesa i Drevesiny Institute* in Russia, where its use as a medicinal has warranted extensive efforts at cultivation. In favourable conditions with traditional (nonspecified) drying methods, bearberry shoots take 13-30 days to dry which, in less favourable cool and moist conditions, can be extended to 30-35 days.

A method to accelerate such conditions was investigated by Mukhina in 1994. When shoots were shredded and put through sieves with 0.3-0.7 cm apertures, drying was markedly accelerated. The shredded material was similar in quality to whole shoots but required half the drying space with increased packing facilitation.

Storage of shredded shoots had no adverse effects on the chemical composition. Research also examined the best means of harvesting bearberry. The operating efficiency of mechanical shoot harvesting was 15-20 times greater than that of manual cutting (Mukhina 1983).

Conversely, methods are being developed for the successful micropropagation of bearberry. Researchers in Brazil were able to proliferate shoot explants on Murashigi-Skoog medium with a low concentration of benzyladenine and then root the shoots on media supplemented with naphtholacetic-acid (Rodriguez *et al.* 1998). Rooted plantlets were transferred to soil and acclimatized with an impressive 90% survival rate.

Products & Uses

• Medicinal Properties

The commercial importance of bearberry is based on a reputation for astringent properties and beneficial effects in nephritis and other diseases of the urinary system (Lewis *et al.* 1977). The antiseptic and diuretic properties claimed for bearberry can be attributed to the hydroquinone derivatives, especially arbutin. Crude bearberry extract has also been suggested as effective in cancer chemotherapy with both uvaol and ursolic acid active in the PS-125 tumour system (Duke 1985).

Diuretic - To justify its use as a diuretic in both tradition medicine and its classification as a phytomedicine by French regulations (Bulletin Officiel 1990), researchers investigated its reputed diuretic effects and found it to indeed cause significant diuresis in rats (Beaux *et al.* 1998). This property had recently come under much scrutiny ("The drug does not have a diuretic effect." Bissett 1994).

Antiseptic - At a dose of 25mg/kg, bearberry phytoextract shows marked antibacterial and nephroprotective effects ascribed to its high concentration of arbutin and other biologically active substances (Nikolayev *et al.* 1996). The crude extract is reported more effective than isolated arbutin.

The antiseptic properties of bearberry include antimicrobial activity versus a considerable range of microorganisms (refer to Moskalenko 1986 for a complete listing). The minimum

inhibitory concentration for arbutin is reported to be 0.4-0.8%, depending on the microorganism (Jahodar et al. 1985).

Its antibacterial activity as a urinary disinfectant is due the presence of metabolic derivatives hydroquinone glucuronide and hydroquinone sulphate in the urine (Bissett 1994). Arbutin is absorbed from the gastrointestinal tract virtually unchanged and during renal excretion is hydrolysed to yield the active principle, hydroquinone, which exerts an antiseptic and astringent action on the urinary mucous membranes (Newall et al. 1996).

Aqueous and methanolic extracts have also demonstrated molluscicidal activity at a concentration of but 50 ppm; activity attributed to the tannin constituents (Schaufelberger et al. 1983).

Anti-inflammatory - Shipochliev et al. (1984) tested the anti-inflammatory action of bearberry and found it effective against several chemical inducers such as carrageenan, histamine and prostaglandins. Bearberry extract has also exhibited significant therapeutic effects against immuno-inflammation when tested for the treatment of contact dermatitis (Kubo et al. 1990).

• **Medicinal Products**

Bissett (1994) describes a wide range of medicinal remedies using bearberry as an ingredient: Uvalysat™-Tropfen (drops) and Arctuvan™ are monovalent preparations, but there are many preparations for urological remedies in which it is combined with other plants or synthetic components, e.g. Cystinol™, Hermiol™, Nephronorm™, etc.

In the UK, bearberry leaf is a component of more than 50 anti-inflammatory products, e.g. Seven Seas Rheumatic Pain Tablets and Backache Tablets (these latter standardized to give 3 mg arbutin), Potter's Sciargo and Potter's Tabritis (both tablets), etc. The leaf and/or extract are also in a range of multi-ingredient products, mostly diuretics, and is available in tea bags and tea pastes.

Locally, bearberry can be found in local pharmacies as an ingredient in at least three herbal diuretics, usually in combination with juniper berry, parsley root and celery seed. It can also be found in capsule form, teas and in bulk, dried leaf form in most health food stores.

Bearberry is an active ingredient in excess of 150 products sold in Canada (Wills et al. 1999).

• **Food Uses**

Bearberries are not very nutritious nor delectable, although they are reported to sweeten when cooked (Craighead et al. 1963). The fruit can be used to make a cooling drink, tea or used for preserves (PFAF) and home-made jams (Chiej 1988). The dried leaves have also been used for smoking as an alternative to tobacco (Bown 1995).

• **Cosmetic Applications**

Bearberry extract is also used in a variety of cosmetic products as a skin-whitening agent. A typical example is the 'White Secrets' cosmetic line of Janssen Cosmeceutical Care which comprises a variety of skin products designed for skin de-pigmentation and lightening. It includes bearberry extract and its active skin bleaching ingredient, arbutin.

Chemical Characteristics **Constituents**

Herb constituents (Newall et al. 1996):

- Flavonoids: Flavonols (quercetin, myricetin) and their glycosides including hypericin, isoquercitrin, myricitrin and quercitrin.
- Iridoids: Asperuloside (disputed), monotropein
- Quinones: Total content at least 6%; mainly arbutin (5-15%) and methyl-arbutin, some piceoside, free hydroquinone
- Tannins: 6-7% (range 6-40%); ellagic and gallic acids
- Terpenoids: 0.4-0.8%, including ursolic acid, uvaol and amyrin derivatives (Barl et al. 1996).

Bearberry forage nutrient content (Crane 1991):

- | | |
|-------------------------|-------|
| • Crude protein | 5.6% |
| • Acid detergent fibre | 26.3% |
| • Acid detergent lignin | 12.9% |
| • Ash | 2.61% |
| • Calcium | 0.62% |
| • Phosphorus | 0.14% |

Toxicology (Newall *et al.* 1996)

Hydroquinone is reportedly toxic if ingested in large quantities: 1g (equivalent to approximately 6-20 g plant material) can cause tinnitus, nausea, vomiting, cyanosis, convulsions and collapse while 5 g (30-100 g plant material) has proved fatal. Concentrations provided by the ingestion of therapeutic doses of uva-ursi are not thought to represent a risk to human health, however, due to the potential toxicity, its use is best avoided during pregnancy and lactation.

Due to its high tannin content, excessive use of uva-ursi should be avoided as it may cause chronic liver impairment. As well, as tannin partakes a bitter and astringent taste, patients with a delicate stomach could lead to nausea and vomiting. The USDA lists no known toxicity (NPDC).

Extracts

Water extraction of dried and ground bearberry aerials produced a clear, dark yellow-orange coloured extract with a very faint scent of freshly-mowed grass with an extractable yield of 37.9% dry plant material.

Ethanol extraction yielded an easily-filterable thick green extract with an extractable yield of 45.5% dry plant matter. Extract solids have a predominantly yellowish colour with some green and brown highlights and is a slightly gummy, crystalline solid.

Patents

There are not many patents restricting the use of bearberry. The most recent patents originate in the United States for uses ranging from cosmetic purposes to medicinal and therapeutic applications.

❖ 05980904 (99/11/09) Leverett *et al.* US
Skin whitening composition containing bearberry extract and a reducing agent.

❖ 5958437 (99/09/28) Zaveri C. US
Dermatological healing kit, components therefor and process for making.

❖ CA2253736 (98/03/26) Squires M. US
Antimicrobial treatment for Herpes Simplex virus and other infectious diseases.

❖ CA2246371 (97/08/21) Sagel *et al.* US
Urogenital and intestinal disorder compositions comprising a substance derived from plant species of the Ericaceae family and a lactic acid bacteria growth factor.

❖ 06024937 JP (94/02/01) Koikawa *et al.*
JAPAN

Mucopolysaccharide fragmentation; inhibiting and/or active oxygen-scavenging agent, antioxidative and cosmetic.

❖ 00568001/EP A2 (93/11/03) Hozumi *et al.*
JAPAN

Antiviral agent containing crude drug; bearberry is only one of many plants listed in this patent.

❖ 61100517 JP (86/05/19) Nanba *et al.*
JAPAN

Novel agent for dental caries; with an active ingredient derived from bearberry

❖ CA1184756 (85/04/02) McLean M.
CANADA

Substitute smoking tobacco product.

❖ CA1192108 (83/03/11) McLean M.
CANADA

Substitute tobacco product for use as cigar tobacco, pipe tobacco or chewing tobacco.

Cost & Availability

Plant part: fruiting aerials

Sask. Availability: Some material is wildharvested, dried and stripped of its leaves for use in kinnikinnick or Native American smoking mixture. Large mats of aerials with fruiting bodies can be found in sandy soils in mixedwood forest eco-region. Harvest time: July-September. *Note:* So as its delicate shallow root system is not destroyed, this material should be cut with sharp power or hand tools.

Sask. Price:

Direct from harvester, whole: \$7/kg

Dealer's Price, milled: \$11/kg

Price/Availability outside Sask.: Uva-ursi leaf is available from Global Botanicals, Barrie Ont. at 10kg minimum price of \$19.11/kg.

Potential Suppliers:

♦ Parkland Botanicals, Togo Sask.
(306) 579-2146

♦ Buck Enterprises, Le Pas Manitoba
(204) 623-5932

♦ Global Botanicals, Barrie Ontario
(705) 733-2117

Buckwheat

Fagopyrum esculentum Moench

Family: Polygonaceae

Common names: Common buckwheat, Beechwheat, Sarrasin, French wheat, Garden buckwheat, Qamh Al Baqar

Scientific pseudonyms: *Fagopyrum fagopyrum* (L.) Karst, *F. vulgare* Hill, *F. sagittatum* Gilib., *Polygonum fagopyrum* L.

Buckwheat is rated as one of the best sources of high biological value protein in the plant kingdom. Compared with products extruded from maize, wheat or barley, extruded buckwheat products are of very high nutritional quality. In addition, buckwheat has significant anti-hypercholesterolemic and anti-diabetic properties regardless of age, body mass or other dietary intakes. In Germany, buckwheat has been heralded 'Medicinal Plant of 1999' by the pharmaceutical journal Pharmazeutische Zeitung. Despite strong market demand and relatively simple agronomy, buckwheat remains a scarce crop in Saskatchewan. Yet the potential for buckwheat products remains tremendous.

Description & Habitat

Buckwheat is an introduced annual herb frequently regarded as a grain crop, although it is phylogenetically classified as a pseudo-cereal (Singh *et al.* 1982). This tall, multi-branched erect plant can grow from 0.6-1.5 m and is supported by a round knotted stem which is hollow and green when young, taking on a reddish-brown hue at maturity. The root is comprised of a shallow taproot system with numerous lateral extensions reaching over one meter in depth.

From the joints in the stem, it is adorned with alternate and oppositely-positioned lateral branches which give rise to large, heart-shaped leaves. In July and again in September appear panicles of numerous, light and freshly-coloured

white or pink flowers. Buckwheat fruit, commonly referred to as seeds, are 4-6 mm long, triangular or polygonal in shape and generally brown in colour with a thick outer hull and inner groat. Buckwheat has indiscriminate growth which persists until cut or killed by frost, thus blossoms may still be present at the top of the plant while lower seeds are already ripe (Pomeranz 1983).

Flowers are equally divided into two types; pins (long pistils, short stamens) and thrums (short pistils, long stamens). Legitimate cross-pollination occurs only between pin and thrum flowers therefore although the plant flowers profusely, only 10-20% of flowers will set seed due to the strict requirement of cross-pollination for legitimate fertilization (Obendorf *et al.* 1991). Buckwheat displays considerable plant to plant variability: some plants set well over 200 seeds while some plants set only 10 to 20 seeds.

Buckwheat exhibits a rapid growth habit with emergence occurring as early as four days after planting and typically maturing in 75-90 days (Edwardson 1996). It is best suited to light, well-drained soils, such as sandy and silty loams (McGregor 1966). On highly fertile soils, buckwheat lodges badly and consequently fills in poorly. Buckwheat is quite temperature-sensitive: excess of 25°C can significantly reduce seed set and yield (Obendorf *et al.* 1991). The limited root system and large leaf surface combine to make the plant susceptible to wilting during periods of moisture stress (Campbell *et al.* 1978).

Cultivation & History

Buckwheat is believed to have originated in central and northeast Asia where it has been widely cultivated since the 10th century in China, later being introduced to Europe through Turkey and Russia during the 14th and 15th centuries (Taira 1974). Global buckwheat production is currently dominated by China, Russia and Ukraine which together account for 90% of global production with world production area as high as 5 million acres (AAFRD). Buckwheat is also grown as a minor crop in Europe, North America, India, Tibet, Tasmania, Australia, Argentina, Bhutan and others. The main buckwheat cultivars grown in Canada are "Mancan" and "Manor" developed by Agriculture & Agri-Food Canada at Morden. A Koto variety was released in 1998 and is scheduled for commercial production in the year 2000 (ACEIS).

In Canada, Manitoba is the leading producer of buckwheat accounting for 75% of the Canadian 1998-1999 production, followed by Quebec at 16% and Ontario at 14% (AAFRD). In Saskatchewan, only 1,000 tonnes was produced in 1997-98. Canadian domestic consumption has ranged from 9,000-12,000 tonnes per year during the past three years and is forecast at 14,000 tonnes on a production area of 32 thousand acres for 1999-2000 (AAFC 1999). The yield for 1999 is forecast to increase to approximately 0.5 tonnes/acre (ACEIS).

Although Canada produces only 1% of the world's buckwheat, it accounts for nearly 10% of world exports (MacMichael 1999). Most Canadian buckwheat production is exported to Japan which, in 1997, accounted for about 62% of total exports with smaller amounts to the Netherlands, US, Germany and Belgium. Opportunities for increased buckwheat production are abundant due to a decrease in Chinese production and a concurrent increase in the export market (MacMichael 1999). Japan consumes over 100,000 tonnes of buckwheat every year, but only produces 20-30% of its domestic needs (Ujihara 1995). Buckwheat production in Canada will be a critical factor in determining Canada's share of the increasing market (ACEIS). Although North American buckwheat exporters currently enjoy solid relationship with the Japanese market, it is desirable to develop additional markets, especially with respect to value-added buckwheat (Edwardson 1996).

The considerably low seed set (10-20%) has been a limiting factor to the development of buckwheat as a major crop. This problem can be partly resolved through the use of insect pollinators which have proven essential in effective fertilization and seed set. Honeybees and leafcutter bees in particular are the most effective buckwheat pollinators (Campbell *et al.* 1978).

Manitoba research recommends one honeybee colony per acre which can yield up to 150 lbs of honey per season (Pomeranz 1983). Placement of two colonies per acre (5 colonies/ha) resulted in 80% of the flowers setting seed, while only one colony for each 2.5 acres (1 ha) provided only 58% seed set (Anon. 1974). An additional benefit of honeybee pollination is the production of marketable honey. Conversely, a high-yielding, self-pollinating experimental strain has recently been bred in Manitoba which

eliminates the need for cross-pollination and dramatically increases seed set (Small 1999). Such methods of increased seed production vastly increase the return of buckwheat production making it a much more viable crop option.

Another limiting factor has been the extreme plant to plant variability which, coupled with higher and more stable yield in other crops, has left buckwheat at a disadvantage with respect to cultivar improvement (Edwardson 1996). However, interspecific hybridization between *F. esculentum* and *F. homotropicum* is now underway (Campbell 1995); this species is self-pollinated and shares many characteristics to *F. esculentum* thus allowing plant breeders to improve and develop new varieties with desirable production and consumption characteristics.

Buckwheat is especially useful as a catch crop or emergency crop to replace a failed crop due to its rapid growth. A good crop can be harvested in some areas when seeded as late as July 1, long after a crop of any other grain could be sown (McGregor 1966). Buckwheat also has the advantage of being very competitive with other plants and weeds due to both its rapid development and allelopathic properties. Research shows that root elongation of weed seedlings is significantly inhibited by water extracts from the soil where buckwheat was cultivated (Tominaga *et al.* 1995). Some organic farmers include buckwheat in their rotation specifically for weed control. As well, disease and insect problems have been infrequent and minimal.

Products & Uses

• Food Applications

Buckwheat is rated as one of the best sources of high biological value protein in the plant kingdom (Campbell *et al.* 1978) and is primarily used for human consumption. The specific proteins and nutraceutical characteristics of buckwheat allow for potential use in extruded products and offer substantial dietary benefits targeted to special nutrition needs. Among its nutritional qualities:

- buckwheat has over 90% of the value of non-fat milk solids and over 80% of whole egg solids (Udesky 1992)

- it is gluten-free, thus making it a valuable nutrient in the diets of people who are sensitive to gluten
- the human body can utilize 74% of the available protein in buckwheat
- buckwheat is virtually fat-free; although other food products are also similar high amounts of available protein, many contain high levels of fat
- buckwheat has nearly twice the amount of lysine found in wheat and white rice
- buckwheat has an excellent amino acid composition that is very complementary to cereal grains (Udesky 1992)
- extruded buckwheat products are of very high nutritional quality when compared with products extruded from maize, wheat or barley alone.

Buckwheat groats, or dehulled seeds, have numerous uses. Roasted groats, which are called kasha, are sold in whole or granulated forms and can be baked, steamed or boiled for nutritious alternative to potatoes and rice. Buckwheat flour is used in pancake mixes and various breads, often blended with wheat flour for use in bread, pasta products and some breakfast cereals.

In Japan, buckwheat is made into soba noodles, a large part of the Japanese diet (Udesky 1992). In eastern Europe, buckwheat is made into breads, cakes and dumplings along with wheat flour or alone in some dishes such as polenta and zganci (PFAF). Buckwheat flour may also be used in deserts, ice cream cones, diuretic foods, canned meat products and canned vegetable products. The potential for including buckwheat in other products is tremendous (Edwardson 1996).

Pasta produced from a mixture of wheat and buckwheat flour, with the addition of egg yolk, vital gluten and skimmed powdered milk has been characterized to possess shorter cooking time. This provides buckwheat with numerous applications in nutritious foods that could be packaged for rapid preparation.

Bees utilized for buckwheat pollination also produce a uniquely dark and strong-flavoured honey which is sold at a premium. Due to the decline of buckwheat as a grain crop, buckwheat honey was so uncommon that it commanded a price higher than that of almost any other honey (Pomeranz 1983).

• **Nutraceutical and Medicinal Uses**

Anti-hypercholesterolemia: Buckwheat protein extract possesses active hypocholesterolemic properties - it controls blood cholesterol build-up. In an experiment comparing buckwheat protein extract, soybean protein isolate and casein, rats fed a cholesterol-rich diet supplemented with buckwheat extract for three weeks had significantly decreased plasma cholesterol level and decreased hepatic cholesterol levels (Kayashita *et al.* 1995). Researchers expect that buckwheat will be useful in the prevention and treatment of hypercholesterolemia.

A major study in China has found that a buckwheat intake of 100g per day is associated with significantly lower total serum cholesterol, low-density lipoprotein cholesterol and a higher ratio of high-density lipoprotein to total cholesterol independent of age, body mass index, alcohol use as well as dietary intakes of energy, cholesterol, sodium and potassium (He *et al.* 1995). Besides the demonstrated hypocholesterolemic effects, these results are also significant in that higher concentrations of high-density lipoprotein protect against coronary heart disease, a further benefit of buckwheat consumption.

Finally, a study by the Johns Hopkins Medical Institute found that people who consumed the greatest amount of buckwheat also had the lowest blood pressures (Jiang *et al.* 1995).

Anti-Diabetic: The slow uptake of buckwheat, due to its slow digestion, has the potential to prevent adult-onset diabetes as well as improve glucose tolerance in those who have developed the disease (Buckwheat Diet 1989).

Recent research has also isolated another buckwheat constituent, fagopyritol (a chiro-inositol carbohydrate and various derivatives) which have been shown to be effective in lowering the symptoms of diabetes in the treatment of type II diabetes (Ortmeyer *et al.* 1993). Fagopyritol could have major medicinal value in treating adult-onset diabetes (NBGN); its application is currently under patent review.

Rutin:

Buckwheat produces rutin, a flavonol glycoside, which increases the elasticity of arteries and prevents their hardening. It is used in medicine to check blood vessels for hemorrhage diseases and to treat high blood pressure (AAFRD). This

compound is currently in demand by the pharmaceutical industry (Small 1999).

• Other Uses

Buckwheat grain is reputed to produce an excellent beer (Phillips *et al.* 1990), as well as production of a brown dye from the flowers and a blue dye from the stems (PFAF). The seed hulls have found prolific use in the production of pillows and futon mattresses. These are advertised to be hypo-allergenic, keep cool throughout the night and be of chiropractic benefit to alleviate neck and shoulder discomfort and headaches. A brief search of the Internet reveals hundreds of sites advertising these products which routinely sell for between 40-50\$. Locally, there appears to be a real demand for buckwheat hulls: the Saskatchewan Food and Agriculture website has received several inquiries about sources of supply.

Buckwheat hulls also make a great mulch as they are organic, odourless, moisture-retentive and neat in appearance. The following product was one of many buckwheat products found on the BirkettMills website (www.thebirkettmill.com).

Chemical Characteristics

Constituents

Buckwheat protein content (Javornik *et al.* 1981):

albumins	18.2%
globulins	43.3%
prolamins	0.80%
glutelins	22.7%
inextractable N compounds	15.0%

Amino acid content as % of whole grain (Thacker *et al.* 1984):

• Arginine	0.90
• Histidine	0.33
• Isoleucine	0.46
• Leucine	0.84
• Lysine	0.77
• Methionine	0.19
• Phenylalanine	0.56
• Threonine	0.49
• Valine	0.60

Buckwheat oil constituents (Belova *et al.* 1969):

• saturated fatty acids	16-20%
• oleic acid	30-45%
• linoleic acid	31-41%

Buckwheat and wheat flour content - mg/100g; Edwardson 1996 and (Pomeranz 1983):

	Buckwheat	Wheat
• Calcium	41 (110)	15
• Iron	4 (4)	1.17
• Magnesium	251 (390)	22
• Phosphorus	337 (330)	108
• Potassium	577 (450)	107
• Sodium	0 (n/a)	2
• Zinc	3.12(0.87)	0.70
• Copper	0.09(0.95)	0.144
• Manganese	0.099(3.37)	0.682

Average nutritional composition of buckwheat seed and groat (Robinson 1980):

	Content %				
	1	2	3	4	5
Buckwheat seed	12.3	73.3	2.3	10.9	2.1
Buckwheat groats	16.8	67.8	3.2	0.6	2.2
Buckwheat dark flour	14.1	68.6	3.5	8.3	1.8
Buckwheat light flour	11.7	72.0	2.5	1.6	1.8
Buckwheat white flour	6.4	79.5	1.2	0.5	0.9

• Key: (1) Protein; (2) Carbohydrate; (3) Fat; (4) Fibre; (5) Ash

Protein content and amino acid content of commercially milled buckwheat (Pomeranz 1983):

	1	2	3	4	5
Protein	13.8	16.4	7.4	19.0	18.9
Lysine	6.0	5.9	5.7	5.2	5.2
Histidine	2.6	2.6	2.7	2.4	2.8
Ammonia	2.1	1.9	2.2	1.7	2.3
Arginine	9.2	10.0	7.9	8.7	9.7
Aspartic acid	11.4	11.4	10.5	11.8	10.8
Threonine	4.0	3.8	4.1	4.1	3.9
Serine	4.9	4.6	4.7	5.5	5.0
Glutamic acid	18.5	19.3	17.6	20.1	19.2
Proline	3.8	3.8	5.1	4.1	4.0
Half cystine	1.6	1.8	1.8	1.5	1.5
Glycine	6.6	6.2	6.2	6.6	6.2
Alanine	4.3	4.4	4.5	4.1	4.2
Valine	5.3	4.9	5.4	5.1	5.1
Methionine	2.3	2.8	2.8	1.9	2.3
Isoleucine	4.0	3.7	4.2	3.9	4.0
Leucine	6.7	6.2	7.0	6.5	6.7
Tyrosine	2.0	2.1	2.9	2.1	2.3
Phenylalanine	4.8	4.8	4.8	4.9	4.7

♦ Key: (1) whole buckwheat; (2) buckwheat groats; (3) light flour; (4) dark flour; (5) buckwheat feed

Vitamin content of buckwheat; mg/1000g (Pomeranz 1983):

• Thiamine	3.3
• Riboflavin	1.2

- Pantothenic acid 11.0
- Choline 440
- Niacin 18.0
- Pyridoxine 1.5
- Tocopherols 40.0

- ◊ In addition, buckwheat was reported to contain considerable amounts of biologically available tocopherols, pigments, sterols and phospholipids (Zalesskaya *et al.* 1976).
- ◊ Fagopyrin, a derivative of naphthodianthrone (which is closely related but less phototoxic than hypericin of St. John's Wort - *Hypericum perforatum*) has been found in varying concentration:
 - present in unspecified amounts (Johnson 1983)
 - ethanolic buckwheat herb extract contains 0.5% fagopyrin (Theurer *et al.* 1997)
 - the amount of fagopyrin in aqueous extract is generally below the level of detection (Theurer *et al.* 1997).
- ◊ Buckwheat also contains the natural bioflavonoid rutin which is rich in the leaves and flowers, but absent in the seeds (Singh *et al.* 1982). Rutin can comprise up to 3% of plant dry weight (Claus *et al.* 1970), with the buckwheat flower containing about 2mg rutin/10 g (Suzuki *et al.* 1987).

Toxicology

Fagopyrin, ingested green or dried, can cause serious photosensitization in animals with sun-exposed or light-coloured skin including cattle, goats, sheep, swine and turkeys. Humans can be sensitized to dust from buckwheat flour after long exposure, although photosensitization has not occurred in humans (Blumstein 1936).

Although all plant parts are considered toxic, little fagopyrin occurs in the seeds (Johnson 1983) therefore only the dehusked grain is considered safe (PFAF). As the amount of fagopyrin in aqueous extract is generally below the level of detection, it is considered borderline or non-phototoxic (Theurer *et al.* 1997).

Extracts

Water extraction of buckwheat seed produced a very viscous, thick extract. Vacuum filtration, gravity filtration and cheesecloth all proved unable to separate the extract from seed

material. Centrifugation finally yielded 435ml of a clear, thick extract with a greasy feel. It is a very light beige colour and has an extractive yield of 9.8%. The residual seed material, post-extraction, is very hard and clumpy solid; a sharp contrast to the fine, white powder material previous to extraction.

Ethanol extraction yielded a high return of clear, light yellow extract with a greenish tinge. Its extractive yield was 13.1% and the solids are comprised of a syrupy, dark brown, sticky molasses-type substance with a strong, sweet smell. Post-extracted seed material appears no different than the pre-extraction material.

Patents

Very few patents exist specifically for *Fagopyrum esculentum*. The US patent office lists 17 patents for buckwheat; only one for *Fagopyrum*. An additional 46 patents were found in the CIPO database when searched for "buckwheat". Most of these deal with various aspects of food preparation or products and apply to buckwheat or a variety of other cereals and grains.

A few patents with specific application to buckwheat are listed below, but it is recommended that those interested in a particular aspect of buckwheat manufacturing revisit the site more thoroughly. An additional patent from Japan exists for production of a tea and a patent from Australia is listed in CIDO.

- ◊ 2264201 (99/02/19) Joseph *et al.*
AUSTRALIA

Manipulation of proanthocyanidin biosynthesis.

- ◊ CA2170964 (99/01/05) Yamada T. *et al.*
JAPAN

Buckwheat starch syrup, method for preparing the same, and foods containing the same.

- ◊ CA2171389 (98/12/08) Yamada T. *et al.*
JAPAN

Powdered buckwheat starch syrup and method for preparing the same.

- ◊ CA2236641 (98/11/07) Obendorf *et al.* US
Preparation of fagopyritols and uses therefor; particularly, for treatment of diabetes.

- ◊ 5344871 (94/09/06) Timm *et al.*
Method of making binder from naturally occurring agricultural products.

- ❖ 05000070 JP (93/01/08) Watabe T.
JAPAN

Production of tea from *Fagopyrum esculentum* Moench and *Ganoderma lucidum* Karst; a method for producing a tea having unique flavour and aroma and further various pharmacodynamic effects with hardly any bitterness.

Cost & Availability

Plant part: seed only

Sask. Availability: Grown as a specialty grain, both conventionally and certified organic.

Sask. Price:

Conventional

Grower direct, bin-run: \$7-\$8/bushel

Dealer's Price, clean: \$8-\$10/bushel

Certified Organic

Grower Direct, bin-run: \$10-\$12/bushel

Dealer's Price, clean: \$12-\$14/bushel

Potential Suppliers:

Certified Organic:

- ❖ Farm Grow Organic Foods, Regina Sask.
(306) 522-0092

Conventional

- ❖ Arlee Dancey, Carievale Sask.
(306) 928-2134

Recommended Resources:

M Edwardson S. 1996. Buckwheat: Pseudocereal and Nutraceutical. In: J. Janick (ed). Progress in new crops. ASHS Press, Alexandria VA.
(www.hort.purdue.edu/newcrop/proceedings1996/v3-195.html)

M Pomeranz Y. 1983. Buckwheat: structure, composition and utilization. *CRC Critical Review in Food Science and Nutrition* **19**(3): 213-258.

Calamus

Acorus calamus L.

Family: Araceae

Common names: Ratroot, Sweet sedge, Sweet flag, Sweet cane, Myrtle flag, Beewort, Cinnamon sedge, Flagfoot

Scientific pseudonyms: *Acorus aromaticus* Gilibert, *Acorus odoratus* Lamarck, *Acorus americanum* (Raf.) Raf., *Acorus calamus* var. *americanus* (Raf.) Wulff

Whether for the pleasantness of its aromatic compounds or its positive medicinal attributes, calamus has become one of the very few plants to attain widespread global usage (Motley 1994). From North to South America, Europe through to Africa, the Middle East to Asia, calamus rhizomes are an important commercial commodity in various industries and of considerable medicinal value. Though its use is currently prohibited by Health Canada due to concerns of the safety of its chemical composition, calamus has not suffered from lack of notoriety. North American varieties do seem to have a special attribute not found elsewhere in the world, however: the absence of the potential carcinogen beta-asarone which has banned its use in Canada.

Description & Habitat

Calamus is an uncommon but widespread plant of aquatic habitats in temperate to subtemperate regions (Motley 1994). It is a herbaceous and aromatic perennial with a sweet, pleasant smell and a pungent bitter taste. It greatly resembles the more common cattail with long, narrow sword-shaped leaves, 8-25 mm wide and up to 2 m tall. Leaves arise from a thick, horizontal, jointed and branched rhizome. The rhizome is often split longitudinally and peeled exhibiting triangular leaf and roundish root scars; it is up to 2 cm thick and 1 m long, whitish with a reddish tinge and soft (Bissett 1994).

Growing at an angle from the leafless, three-sided flowering stem is a long cylindrical spadix bearing yellow-green flowers (Bunney 1992). Calamus reproduces by rhizome division and is therefore often found in dense, pure stands alongside swamps, marshes and quiet streams or lakeshores. Fruits are red and berry-like, hard and dry on the outside, gelatinous on the inside (Johnson *et al.* 1995), containing a few ovate seeds (Chiej 1988). It prefers growing in shallow water or in a very moist loamy soil with much sun (PFAF).

Acorus calamus L. has differing degrees of ploidy: var. *americanus* Wulff (diploid), var. *calamus* (triploid) and var. *angustatus* Engl. (tetraploid) (Bissett 1994), each of which has varying habitats and essential oil compositions. The type of calamus found in North America is the diploid variety. The sterile triploid is distributed throughout Europe, temperate India and the Himalayan and the tetraploid variety is found in eastern and tropical southern Asia including Japan and Taiwan (Motley 1994).

Acorus gramineus, a species also commonly utilized in eastern medicine and often times used interchangeably with *Acorus calamus*, is distinguished by the lack of sesquiterpenoids in the essential oil (Sugimoto *et al.* 1997). Further genetic analysis has clearly distinguished *Acorus gramineus* from *Acorus calamus* (Sugimoto *et al.* 1999).

Cultivation & History

Calamus has a rich and diverse ethnobotanical history. The plant was known in early Greek and Roman medicine (Motley 1994) and its remains were one of many plants found during excavation of the tomb of King Tutankhamen (Bown 1988). Calamus is thought to be indigenous to India, having been spread along early trade routes (Motley 1994). Its various degrees of ploidy, however, suggest that there are probably various varieties native to each particular area.

In North America, there is extensive usage of calamus in Native medicine and folklore. Calamus is one of the most widely and frequently used herbal medicines among the Chipewyan; its rhizomes were so widely utilized and valued, that they even became a mode of currency (Johnson *et al.* 1995).

The first record of sweet flag cultivation was in 1574 by the Austrian botanist Clusius, who obtained a rhizome from Asia Minor and propagated it in Vienna (Grieve 1992). Calamus is readily propagated by division of rhizomes in the early spring or at the commencement of autumn and rapidly becomes established (Grieve 1992). It can also be propagated by bare root cuttings and by sprigs (NPDC). The optimal planting density is 2,700-4,850 plant per acre. Calamus grows in medium to coarse textured soil and has a medium fertility requirement. Its preferred soil pH range is slightly acidic to neutral; 5.2-7.2 (NPDC).

Cultivation trials in India with new rhizome sprouts collected from old plants showed that varying plant spacing does not produce any significant increase in per plant rhizome yield (Shrivastava *et al.* 1996). However, in terms of rhizome yield on a unit area basis, the highest per hectare rhizome yield was at the closest spacing of 30x30 cm. The same researchers also found that the addition of sand and organic fertilizer (cow dung) promoted better spread and higher yield of rhizomes, as did irrigation at two-day intervals.

Cultivation experiments in Slovenia show that cultivation of calamus may produce significantly higher yields than collection of wild stands. Trials showed that the production potential in the field was 17.6-20.1 kg dry rhizomes/100m² and up to 116 kg/100m² in small cultivated plots (Rode *et al.* 1996).

Although cultivation of aquatic plants may present a number of practical difficulties, researchers at the University of Calicut in India are investigating methods of micropropagation to facilitate this endeavour. Young rhizome buds were cultured on a solid medium supplemented with growth factors which induced multiple shoot production (up to 26 shoots/explant), then the regenerated plantlets were successfully established in soil (Harikrishnan *et al.* 1997). Rhizomes are gathered generally after two or three years before they lose their firmness and become hollow (Grieve 1992). Early spring or late autumn is the recommended time for collection.

Products & Uses

• Food & Cosmetic Uses (PFAF)

The rhizome of calamus can be peeled and washed to remove the bitterness and then eaten

raw like a fruit, roasted as a palatable vegetable or ground and used as a flavouring. The dried and powdered rhizome has a spicy flavour and is used as a substitute for ginger, cinnamon and nutmeg. The young and tender inflorescence is especially popular with children as it is quite sweet. The leaves can also be used to flavour custards in the same way as vanilla pods.

In flavouring and perfumery, calamus provides a bitter tang to foods and special nuances to perfumes; it is also used in toothpaste (Chiej 1988). Calamus is used a great deal in the making of alcoholic drinks (beer, gin and liqueurs such as Benedictine and Chartreuse). In the Depression years, calamus was chewed in lieu of tobacco.

• Medicinal Applications

Calamus is used in powders, teas and drops as a stomachic and carminative; also added to bath preparations to alleviate nervous exhaustion (Bunney 1992). Native medicinal uses included smoking or chewing the rhizome to treat cold symptoms, softening the rhizome in water to treat and aid the healing of cuts and applying a poultice of chewed rhizome to treat sore muscles and painful rheumatic joints and muscles (Johnson *et al.* 1995).

The British Herbal Pharmacopoeia lists calamus as a carminative and spasmolytic agent used for gastritis, gastric ulcer, acute and chronic dyspepsia and intestinal colic. Asarone (trimethoxy-allyl-benzene), a component of calamus oil, has been demonstrated to induce a tranquilizing action (Menon *et al.* 1967). German studies show that for maximum efficacy and safety against spasms, diploid American strains, devoid of beta-asarone, should be used (Foster *et al.* 1990).

Recently, extract of calamus has been shown to exert a highly significant cytoprotective effect in rats against gastric lesions induced by various necrotizing agents, as well as anti-secretory and anti-ulcer effects (Rafatullah *et al.* 1994). Further studies on acute and chronic toxicity are needed to assess the safety of calamus before any human studies are undertaken, but if beta-asarone free calamus is shown safe, calamus will great potential as a treatment for gastric ailments.

Calamus root extracts are present, usually in small amounts, in many multi-ingredient products, mostly gastrointestinal remedies and a

few cholagogues i.e. CarvominTM and GastrolTM (Bissett 1994). Calamus may be combined with Althaea and Filipendula for gastric inflammation and Zingiber and/or Dioscorea for flatulent colic (BHP 1991). The essential oil of diploid calamus (beta-asarone free) was also found to have spasmolytic activity not found in the beta-asarone rich oil (Locock 1987).

• **Additional Uses** (PFAF)

Uses for calamus leaves also include thatching, weaving and basketry while the essential oil is used as an incense, insect repellent and insecticide. The essential oil is effective against houseflies and significantly reduces loss caused by insect damage in granaries. Calamus also has numerous antibacterial, antileech, insecticidal and antifungal properties which suggests further investigation for commercial exploitation as an organic, natural pesticide valuable for agricultural purposes (refer to Motley 1994).

Some sesquiterpenoid compounds isolated from calamus extract have demonstrated potent anti-germination activity and find useful applications as such (Nawamaki *et al.* 1996).

Chemical Characteristics

Constituents (Newall *et al.* 1996)

- **Volatile oil** (1.5-3.5%):
 - calamenol (5%)
 - calamene (4%)
 - calamone (1%)
 - methyl eugenol (1%)
 - eugenol (0.3%)
 - sesquiterpenes acolamone, acoragermacrone and isoacolamone
- **Amines**: Dimethylamine, methylamine, trimethylamine, choline.
- **Tannin**: 1.5%
- **Others**: bitter principles (i.e. acorin and acoretin), acoric and palmitic acids, resin (2.5%), mucilage, starch (25-40%) and sugars.
- **Additional compounds include**: acoragermacrone, acoric acid, acorine, acorone, acoroxide, asaraldehyde, asaronaldehyde, asarone, beta-asarone, azulene, calamenol,

calamenone, calamol, camphene, camphor, choline, cineole, dextrin, dextrose, dimethylamine, eugenol, n-heptylic acid, isoacolamone, isoacorone, linalool, methylamine, palmitic acid, parasarone, pinene and trimethylamine (Duke 1985).

Whereas the North American diploid variety has no beta-asarone, its concentration can be as high as 96% in the Indian tetraploid variety and 5% in the European triploid.

Besides the presence of beta-asarone, calamus varieties also differ greatly in the number of volatile constituents of the oil. The triploid European variety contains 184 compounds, the tetraploid variety contains 93 while the diploid North American variety contains 243 (Motley 1994). Using chromatography, the major components of diploid calamus were found to be monoterpene ketones (15%), sesquiterpene ketones (34%) and acorones (23%) (Locock 1987).

Toxicology

Concern about the safety of calamus revolves primarily around the presence of beta-asarone which has demonstrated carcinogenic, mutagenic and chromosome-damaging properties (Bissett 1994). Subjects in a rat feeding experiment demonstrated death, growth depression, hepatic and heart abnormalities, serious effusion of the abdomen as well as malignant duodenal tumours when supplemented with Indian calamus oil (Newall *et al.* 1996).

However, the North American diploid variety is devoid of this hazardous component and other toxic phenylpropane derivatives (Motley 1994). In view of the toxic properties documented for the oil and associated with beta-asarone, it has been recommended that only beta-asarone free calamus root be used in phytotherapy (Newall *et al.* 1996).

Generally, the oil is considered to be non-irritating, non-sensitizing and non-phototoxic, except for a few cases of erythema and dermatitis in hypersensitive individuals (Opdyke 1977).

The FDA classifies calamus as an "unsafe herb"; it is prohibited from use in human food in both the US and Canada. The Council of Europe lists calamus as a source of natural food flavouring such that calamus can be added to foodstuffs in the traditionally accepted manner, although there is insufficient information available for an adequate assessment of potential toxicity. The

level of beta-asarone permitted in foods is restricted to 0.1mg/kg in foods and beverages and 1 mg/kg in alcoholic beverages.

Extracts

Ground calamus root has a very strong, sweet smell and grinds to a slightly fibrous light yellow powder. Water extraction produced an opaque, viscous golden-brown liquid with a strong spicy-sweet odour and an extractive of 24%. Dried solids are a reddish-brown crystalline solids while the residual extracted root material retains an additional clumpiness.

Ethanol extraction yield a strongly scented, clear, light-orange/light-brown (amber) coloured liquid with an extractive yield of 15.6%. Dried solids are a yellowy-molasses coloured, oily solid while the residual plant material much resembles the starting material.

Patents

There have been no US patents for *Acorus calamus* since 1976 and only one exists in CIPO for an encapsulation method involving calamus or a variety of other herbs. There do exist many patents from Asia mainly for cosmetic and cigarette products:

- ❖ 10324636 JP (98/12/08) Mihara T. JAPAN

Preventing and improving agent (containing asarones or an essential oil containing asarones derived from *Acorus calamus*) for visual impairment

- ❖ CA2166285 (95/11/10) Carstens et al. GERMANY

A food additive for improving immunity; calamus is one of several extracts to be selected.

- ❖ 95196472 (95/08/01) Sakai W. JAPAN
Bath preparation or skin cosmetics containing fermented *Acorus calamus* extract

- ❖ 07196472 JP (95/08/01) Sakai W. JAPAN
Method for producing extract of *Acorus calamus*: involves the addition of malted rice

- ❖ 1102963 (95/05/31) Wang, B. CHINA
Healthful herbal cigarette of non-tobacco type

- ❖ 1101796 (95/04/26) Wu L., R. & S. CHINA
Pesticide for control of oncomelania

- ❖ 07017846 JP (95/01/20) Honda S. JAPAN

Skin external preparation: with a whitening effect and anti-inflammatory activity
An additional Japanese patent exists for an aquaculture method for cultivation plants utilizing bottomless containers and vegetable fibre.

- ❖ 1082096 (94/02/16) Chu C. et al. CHINA
Liquid fuel composition with health-care medicines and its preparation

- ❖ CA2068039 (93/06/28) Yuri et al. JAPAN
Repellent for use against Ixodidae; one of several utilizable essential oils.

- ❖ 1093958 (92/10/05) Zhang T. CHINA
Additive for cigarette

- ❖ CA1269329 (90/05/22) Eguchi et al. JAPAN
Weakly acidic bath-additive preparation.

Cost & Availability

Plant part: root or rhizome

Sask. Availability: Small quantities (5 kg or less) available in early spring when flooded unused food caches of beaver and muskrat are floating downstream or in autumn when water levels have declined and digging is easy. Wildharvest.

Sask. Price:

Direct from harvester, whole: \$31.00/kg
Dealer's price, whole or milled: \$40.00/kg

Note: Wild *Acorus calamus* prices are very high due to strong demand in Native American ceremonial marketplace. Health Canada has banned this item for sale in any form in Canada due to its alleged carcinogenic constituent - beta-asarone. Some commerce persists both in published catalogues (Richter's), retail outlets (Regina's Painted Buffalo Trading Post) and underground at pow-wow's, etc where dry roots sell for a dollar or two each.

Availability outside Sask: Processors may import *A. calamus* from Europe or the USA, but do so at risk of having shipments confiscated by Canada Customs.

Potential Suppliers:

- ♦ Pacific Botanicals, Grant's Pass Oregon, USA (541) 479-7777
- ♦ Parkland Botanicals, Togo Sask. (306) 597-2146 (research only).

Recommended Resources:

M Motley, Timothy J. 1994. The ethnobotany of sweet flag, *Acorus calamus* (Araceae).

Economic Botany **48(4)**: 397-412.

- an excellent comprehensive review of the history, chemistry, ethnobotany and a summary of experimental data

M Locock, R.A. 1987. *Acorus Calamus*.

Canadian Pharmaceutical Journal **120(5)**: 341-344.

- presents many uses of calamus by North American Indians as well as detailed information about the various calamus varieties and their constituents

Canaryseed

Phalaris canariensis L.

Family - Poaceae (Gramineae)

Common names - Canarygrass, Annual canarygrass, Birdseed grass

Scientific pseudonyms - none current

In spite of the importance of canaryseed to the world birdseed trade and a promising nutritional profile, the potential role of this seed for human nutrition remains largely unexplored (Putnam et al. 1996). Canaryseed has always been a one-market crop: a major component of bird feed. Due to irritating and potentially carcinogenic siliceous spicules on the seed hull, canaryseed has not been deemed desirable for human consumption. However, with new spicule-free varieties being developed, alongside the refinement of spicule-removing chemical treatments, the potential of this crop for food and industrial applications can now be further evaluated. Exciting recent research suggests that the composition of small granule starch and gluten-like proteins, rich in tryptophan, may devise unique functional and nutritional properties for canaryseed groats.

Description & Habitat

Canaryseed, otherwise known as canarygrass outside of North America, is an annual herbaceous member of the grass family. Seedlings resemble corn seedling, with fine leaves and purple-red colouration at the base of the stem. Mature plants grow to a height of one meter and have seed heads 2-5 cm in length, much resembling flax. Canaryseed is anchored by a shallow and fibrous root system.

The brown seeds are covered by a thin papery and glossy yellow hull which are covered by minute siliceous spicules (AAFRD). Birds will dehull the seeds prior to consumption. The spicules are severe skin irritants and have been linked to esophageal cancer when present as contaminants in wheat flour (O'Neill et al. 1980), a finding that has greatly discouraged human usage.

Canaryseed is a cool season crop which prefers long warm days and cool nights, making it well adapted to western Canada, with the exception of the drier parts of the brown soil zone (AAFRD). Due to its shallow roots, it is more sensitive to heat and drought than wheat. It does best on heavy, moisture-retentive soils (SAF). Canaryseed grows to maturity in 105-110 days and is noted for poor seedling vigour with low growth rates prior to tillering (4-leaf stage). This makes canaryseed poorly competitive with weeds, but with adequate plant density and proper nutrition, a dense cover is typically established.

Cultivation & History

Canaryseed is native to the Mediterranean and the Middle East although, quite appropriately, the Canary Islands are thought to be its genetic epicenter (Nagy 1996). It likely developed as a harvested crop in northern Africa or the western Mediterranean region (Putnam et al. 1996). It is currently cultivated in Argentina, Australia, Hungary, Mexico, the United States and Canada. Cultivation of canaryseed in North America began in North Dakota and Minnesota shortly after the second world war. Contract production of canaryseed began in Manitoba in 1957 and it is now in major production throughout Canada (SAF).

Canada currently accounts for approximately three-quarters of the annual global canaryseed production of 205,600 tonnes. Expected canaryseed production statistics for 1999 includes a yield of 0.44 tonnes/acre, volume of 171 thousand tonnes and a total area of 388 thousand acres (ACEIS). Most Canadian production is exported; very little product is utilized domestically (AAFRD). Domestic utilization ranges between 10-30% while the remainder, approximately 125,000 tonnes, is exported (Small 1999). Northern Europe annually consumes about 26 thousand tonnes of canary seed alone (ACEIS). Canadian shipments to Belgium rose by 86% in 1997/98 to 32,358 tonnes. In North America, the US imports about 15-20 thousand tonnes of canary seed annually and Mexico has become one of the largest markets, importing 20-30 thousand tonnes annually (ACEIS).

In 1995, Saskatchewan produced over 90% of total Canadian production (SAF). A tremendous increase in production of 98% was seen in 1998, almost 100,000 tonnes higher than in

1997 (SCR). This significant increase in production was due to an increase in global demand as well as an increase in both seeded area and yield, which increased by 10% in 1998 to 989 lbs/acre.

The cultivars Keet and Elias are pure line selections from USDA plant introductions from Iran (Putnam *et al.* 1996) and account for the majority of production. A new cultivar, CDC Maria recently developed by the University of Saskatchewan, is a glabrous (hairless seed) variety in which the spicules are completely absent from the seeds. This cultivar is expected to revolutionize the industry (Small 1999). CDC Maria is adapted to the traditional canaryseed growing regions of Saskatchewan in the dark brown and brown soil zones. The elimination of silicified hull trichomes has led to a reduction in skin irritation, increased test weight (+11%) and kernel weight (+4%), although it is lower in yield than Keet (Hucl *et al.* 1998). In regards to grain composition, there doesn't appear to be any significant difference between CDC Maria and Keet (refer to Table 1 in Chemical Characteristics - Constituents).

Canaryseed is quite frost-resistant; producers have reported seedlings surviving daily minimum temperatures of -5°C (Putnam *et al.* 1996). Tillage requirements are generally similar to those of other small grains with moldboards plowing producing the highest yields. Recent improvements in direct-seeding equipment technology, coupled with a marked increase in producer knowledge and management of reduced tillage systems, has facilitated success with direct-seeding of annual canarygrass (Putnam *et al.* 1996). For detailed agronomic information about canaryseed, refer to "Canaryseed in Saskatchewan", a FarmFacts publication produced by Saskatchewan Agriculture & Food and available at any Rural Extension Office (also available on the SAF website).

Products & Uses

Canaryseed has potential as a food grain crop based on its unusually high amino acid concentration and its crude protein and oil concentration which together lead to a more favourable nutritional balance than many cereals (Putnam *et al.* 1996).

With the advent of chemical treatments and modified genotypes to eliminate the spicules, the functional and nutritional properties of this

grain have been thoroughly investigated. In a 1997 study of the structure and composition of canaryseed by Abdel-Aal (*et al.*) of the University of Saskatchewan, canaryseed was found to have unique functional and nutritional properties. Among some of the findings:

- 1) High concentrations of cystine, tryptophan, phenylalanine and arginine, combined with low levels of lysine and proline, suggests a unique protein structure and functionality for canaryseed protein.
- 2) Low concentrations of lysine and high concentrations of arginine provide a low lysine/arginine ration found to be hypocholesterolemic in soybean (Kritchevsky 1979); the ratio was 0.9 in soybean protein, whereas it was found to be an even lower 0.2 in canaryseed.
- 3) The high protein contents (average 18.7%) and predominance of prolamin and glutelin fractions (78%) in the proteins suggest unique functional properties.
- 4) Canaryseed oil is highly unsaturated, containing mainly linoleic, oleic and palmitic acids (Malik *et al.* 1966).
- 5) Crude oil showed excellent antioxidant activity, owing to derivatives of caffeic acid (Takagi *et al.* 1980). Antioxidant activity is nearly equal to that of tocopherol and superior to that of hemp (Putnam *et al.* 1996).

In addition to food potential for humans, there is also potential for the use of canaryseed for cosmetic purposes (Small 1999).

Chemical Characteristics **Constituents**

Amino acid profile of canaryseed; expressed as % seed dry weight (Putnam *et al.* 1996):

• glutamic acid	5.94%
• leucine	1.55%
• arginine	1.26%
• proline	1.22%
• phenylalanine	1.18%
• aspartic acid	1.01%
• valine	0.91%
• isoleucine	0.82%
• alanine	0.80%
• serine	0.77%
• tryptophan	0.64%

• tyrosine	0.54%
• glycine	0.53%
• threonine	0.47%
• cystine	0.45%
• histidine	0.43%
• lysine	0.42%
• methionine	0.29%
• amide N	0.47%
• TOTAL	19.73%

Chemical composition of canaryseed bran and flour; percent dry basis (Abdel-Aal et al. 1997):

	<i>Bran</i>	<i>Flour</i>
• yield	25	75
• starch	35.1	66.8
• protein	21.4	20.2
• crude fat	12.7	5.6
• ash	6.3	0.7
• sugars	1.8	1.5
• soluble fibre	2.1	0.1
• insoluble fibre	16.7	0.9
• total digestible carbohydrates	36.9	68.3
• total carbohydrate	55.7	69.3
• total constituents	96.1	95.8

Comparison of selected amino acids with wheat; g/100g protein (Abdel-Aal et al. 1997):

	<i>canaryseed</i>	<i>wheat</i>
• cystine	3.3	2.3
• tryptophan	2.8	1.2
• phenylalanine	6.7	5.4

Composition of two canaryseed varieties compared to wheat (AAFRD):

% dry basis	<i>CDC Maria</i>	<i>Keet</i>	<i>Wheat</i>
Starch	61.2	59	59.8
Crude Protein	21.6	22.3	17.3
Total dietary fibre	5.9	8.3	12.8
Crude fat	7.7	2.1	1.6
Total ash	n/a	2.1	2.1

• *Minerals (mg/ 100g)*

Phosphorus	640	590	430
Potassium	385	340	355
Magnesium	200	195	155
Calcium	40	40	20
Sodium	10	10	10
Iron	6.5	5.9	4.2
Manganese	6.3	7.1	5.9
Zinc	3.9	3.5	2.5
Copper	0.2	0.2	0.3

• *Vitamins (mg/ 100g)*

Thiamine	0.85	0.79	0.44
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Riboflavin	0.16	0.16	0.15
Niacin	0.68	0.89	7.29

• *Antinutrients*

Phytate (mg/g)	18.1	17.5	9.4
Trypsin inhibitor	0.56	0.51	0.47

Fatty acid composition of canaryseed compared with wheat (Abdel-Aal et al. 1997):

	<i>canaryseed</i>	<i>wheat</i>
• oleic	29.3	16.6
• linoleic	55.1	61.2
• palmitic	10.9	15.8
• linolenic	2.5	4.6

The antioxidant components in canary seed (Takagi et al. 1980):

- cycloartenol
- gramisterol
- sitosterol
- campesterol
- 24-methylenecycloartanol
- obtusifoliol
- brassicasterol
- delta7-stigmasterol

These components are all phytosterols with the first four being the main components and the remaining minor components.

Protein composition of canaryseed; % of total protein (Abdel-Aal et al. 1997):

- albumin 5.7
- globulin 7.4
- prolamin 45.5
- glutelin 32.2

Toxicology

The obvious toxicological problem with canaryseed is the presence of noxious silicate spicules, which as previously mentioned, have been linked to esophageal cancer in humans and skin cancer in laboratory mice and livestock (O'Neill et al. 1980). Varieties such as CDC Maria, however, eliminate this threat to human consumption.

Otherwise, there is not much information on the toxicity of canaryseed due to its limited usage as birdfeed. However, it is generally felt that any deleterious effects of seed components would surely have been remarked by the generations

of birds that have had canaryseed as their main, dietary staple.

Extracts

Water extraction of ground canaryseed produced a highly viscous, opaque, yellow-greyish extract with a sweet and somewhat boozy odour and an extractive yield of 28.4%. Filtration of this extract was very difficult due to its thickness and small shell material which tended to punch holes in filter paper during vacuum filtration.

Extract was finally centrifuged to remove residual material which yielded separation of four distinct layers: a dark seed material at the very bottom, a semi-solid beige later which looked much like a fatty material, a beige-yellow liquid and finally a white, wispy filmy material near the top of the liquid fraction. Residue extraction material is a dark, clumpy and solid material not much resembling the starting material; a white powder with some bits of yellow shell material.

Ethanol extraction produced an opaque, bright yellow extract with a milky quality and an extractive yield of 7.9%. Concentration of this material produced precipitation of a yellow solid with a strong syrupy-sweet smell. Solids obtained from the extract are a golden-brown coloured oil with a mostly bland, but slightly sweet, oily smell. Material residue remained a loose, flour consistency with bit of shell material.

Patents

As far as patents go, canaryseed appears to be completely unconstrained. No patents were found for "Phalaris" or "canaryseed" on the US PTO nor were any on CIPO. A single nonspecific patent appears to exist in Europe; a 1987 Italian patent listed below:

♦ 04681752 (87/07/21) Melillo G. ITALY
Capsules containing the active principle of an allergen and process for their preparation.

Cost & Availability

Plant part: seed only

Sask. Availability: Commonly grown under contract in Saskatchewan. Some canary seed traded on the spot market.

Sask. Price:

Conventional

Grower Direct, bin-run: \$0.23-\$0.31/kg

Dealer's Price, clean: \$0.35-\$0.45/kg

Potential Suppliers:

♦ Finora Canada Ltd. Vancouver B.C.
(604) 597-2060

Recommended Resources:

M Putnam D.H., Miller P.R. & Hucl P.
1996. Potential for production and utilization of annual canarygrass. *Cereal Foods World* **41**(2): 75-83.

- an excellent review of the agronomic characteristics of canaryseed, as well as its composition and physical properties, marketing and distribution

M Abdel-Aal, E-S. M., Hucl P.J. & Sosulski F.W. 1997. Structural and compositional characteristics of canaryseed (*Phalaris canariensis* L.) *Journal of Agriculture and Food Chemistry* **45**: 3049-3055.

- a comprehensive description of canaryseed constituents and potential for food and nonfood applications

Caragana

Caragana arborescens Lam.

Family: Fabaceae (Leguminosae)

Common names: Siberian peatree, Peatree, Ning tiao

Scientific pseudonyms: none found

Caragana has historically been principally used as a shelterbelt species. Its hardy growth characteristics ideally suit it to the harsh Saskatchewan climate and it has readily become integrated into the landscape. However, little attention has been paid to the utilization of this species in other faculties. Caragana is considered to have excellent potential to become a staple crop in areas with continental climates: the seed is nutritious, wholesome and easily harvested.

Description & Habitat

Caragana is an introduced deciduous shrub that can grow from a single stem in a tree-like fashion or can be multi-branched to form a wide and expansive shrub. It has an upright growth habit and its branches seldom spread, until the shrub is old (AAFRD). Its leaves are compound and pinnate; each leaf comprised of 8-12 pale green leaflets (Looman 1987). The leaflets have a dark green upper surface and a pale green underside, with smooth edges and elliptic shape (AAFRD).

In late June or early July appear bright yellow flowers, sometimes in clusters, which are very 3-5 cm long, usually form by late July. Pods rupture explosively with an audible pop in late summer to release an average of 6 kidney-shaped, reddish-brown seeds. There are approximately 19,000 seeds per pound (NPDC). If kept dry, these seeds can remain viable for three and sometimes four years (Ross 1931). When left to grow naturally and undisturbed, caragana can become substantially large with a height of 5-6 m (Ross 1931) and width of 4 m (PFAF).

Caragana possesses nitrogen-fixing capability, forming symbiotic root nodules with the soil bacteria *Rhizobia* (Duke 1983). It is a very hardy plant; fast-growing, drought resistant, tolerant of very alkaline soils and extreme temperatures. Caragana prefers a continental climate and reportedly does not grow well in areas that do not have very cold winters (PFAF). In the United States, caragana growth is stunted south of Nebraska (Duke 1983). It can be found growing just about anywhere: on riverbanks, sands, forests, stony slopes, open prairies and gully slopes (PFAF).

Cultivation & History

Caragana is native to Siberia and Manchuria and was introduced to Saskatchewan early in the 20th century. It is now widely established throughout the prairies and much of Canada. Due to its extreme hardiness, density of growth and ability to withstand long period of drought, caragana proved an invaluable plant for use as a shelterbelt in Saskatchewan to combat soil drifting and act as a windbreak to protect crops (Ross 1931).

Caragana grows on fine to medium textured soil with a pH range of 6-9. Rhizobium inoculation does not significantly affect its growth or influence the development of seedlings (Duke 1983). The optimum planting density is 700-1700 plants per acre (NPDC) or 75-150 per linear meter. In multiple rows, caragana should be planted 5-8 m between rows (AAFRD). Caragana grows rapidly in spring and summer and has a minimum precipitation requirement of 22 cm. Its annual growth rate can range from 15-45 cm until maturity, providing ideal growing conditions (AAFRD). It takes about 3-5 years to reach commercial bearing age with good crops occurring nearly every year thereafter (Duke 1983).

Caragana can be propagated by seed, root cuttings, layering or grafting (Duke 1983). Side trimming encourages new growth and prolongs its lifespan, although mature caragana should not be trimmed to less than 3 m in width (AAFRD). It is recommended to seed caragana in autumn, with germination generally to follow two or three weeks of 20°C temperatures (PFAF). The optimum time for hand collecting seed occurs within less than two weeks, usually in July or August (Duke 1983). Cuttings of half-

ripe wood should be taken in July or August (PFAF).

Products & Uses

• Wood and Shelterbelt Uses

The principle use of caragana in Saskatchewan is as a shelterbelt or ornamental shrub.

However, caragana has been used for a variety of other uses including:

- leaves produce a blue, azure dye
- bark provides a fibre used to make cordage
- young pods and seed can be used as a vegetable both by humans and wildlife
- branches are used for arts and crafts

• Medicinal Uses

According to the Dictionary of Chinese Traditional Medicine (Kiangsu 1977) the whole plant, which is known as ning tiao, can be used for cancer of the breast, dysmenorrhea and other gynecological problems.

• Food Uses (PFAF)

Caragana seeds are nutritious and wholesome, although somewhat bland in taste. They can be eaten raw or cooked, as can the pods. Caragana has excellent potential to become a staple food crop. Caragana has also been used for honey production.

• Bioremediator

Caragana is a soil-improving plant due to its nitrogen-fixing abilities and has been used for revegetation of disturbed soils. Due to its extensive root system, caragana can also be used for erosion control (especially on marginal land) or to stabilize riverbanks.

Chemical Constituents

Seed composition (Duke 1985):

- ash 3.4-3.6%
- protein 35.5-36.4%
- oil 13.2-13.6%
- also contains a lectin or phytohemagglutinin

The presence of the flavonoids rutin, quercetin and isoquercitrin has also been reported in the leaves and flowers (Boinik *et al.* 1986).

Toxicology

Although the plant has been claimed poisonous, precise information to substantiate this claim is lacking. The occurrence of the quinolizidine alkaloid cystisine, which has principally nicotine-like stimulating activity, in the seed is doubtful (Bisset 1984). The USDA lists no toxicity (NPDC).

Extracts

Water extraction of ground dried caragana leaves, twigs and pods produced a clear, yellow extract with a slight orange tinge. It has a faint, acrid pea smell and an extractive yield of 28.5%.

Ethanol extraction yielded a dark green, seemingly clear extract with an extractive yield of 13.9%. The extract solids are a slightly iridescent brown solid with a greenish-yellow hue. It has a sweet, autumn smell.

Patents

CIPO lists 5 patents when searched for *Caragana arborescens*; all involve devices or methods for separating and assaying blood or cholesterol (2217210; 2078427; 2031975; 1310905; 2108105). There are three other patents from the US which also utilize Caragana lectins (two of which are the same as CIPO patents 1310905 and 2108105):

- ❖ 9509641 (95/04/13) Oldham M.J. *et al.* US

Using lectins for contraception, prophylaxis and therapy of sexually transmitted disease.

- ❖ 00597268/ EP B1 (99/05/06) Kozak M. *et al.* US

device and method of assaying whole blood for high-density lipoprotein cholesterol

- ❖ 00295526/ EP B1 (92/04/22) Genshaw *et al.* US

Process and device for separating and testing whole blood

Cost & Availability

Plant part: twigs and leaves

Sask. Availability: This hardy shrub was widely planted as a drought-tolerant shelterbelt around farmyards and in fields during the 1930's. It can still be found in large quantities in southern Saskatchewan. Although not commercially

harvested, large orders would attract wildcrafters to this material.

Sask. Price:

Harvester Direct, chipped: \$5/kg

Dealer's Price, milled: \$7.00-\$9.00/kg

Note: As with most quoted price ranges, the price drops when large volumes are contracted.

Potential Suppliers:

♦ Parkland Botanicals, Togo Sask.
(306) 597-2146

Recommended Resources:

M Duke, J.A. 1983. Handbook of Energy Crops. Unpublished.

(www.hort.purdue.edu/newcrop/duke_energy/Caragana_arborescens)

- the best source of collected data on caragana including uses, folk medicine, chemistry, cultivation and harvesting, yields and economics and more.

Caraway

Carum carvi L.

Family: Umbelliferae

Common names: Anis, Alcaraves

Scientific pseudonyms: *Apium carvi*

In 1998, Saskatchewan produced 4.6 million pounds of caraway seed. Much of it is exported and little secondary processing is locally performed. Caraway is a well-established staple in the spice and flavour industry and with increasing scientific verification of its medicinal properties, it also has much potential as a nutraceutical and medicinal agent. Among its various therapeutic uses include anti-asthmatic properties and the induction of a detoxifying liver enzyme thought to be a major cancer preventative. The caraway oil market also shows potential for increased usage in industrial products.

Description & Habitat

Caraway is an introduced biennial or perennial herb with an erect hollow stem. In its first year of growth, bushy green foliage grows to a height of about 20 cm (Fairbairn 1995). The following summer, most plants will set seed with even some further seed production in its third year. Flowers are produced in terminal compound umbels comprised of five-petalled pink or white flowers. Caraway flowers attract parasitic wasps to the garden which prey on aphids and so help to reduce populations of insect pests (Bown 1995).

Finely divided and feathery leaves adorn branched, furrowed stems while a deep-rooted spindle-like taproot anchors the plant. Much literature compares the caraway plant to that of the carrot, a sibling from the parsley family. Caraway fruit is an oblong ribbed achene, a dull brown in colour, containing two crescent-shaped seeds. The seeds are about 2 mm long, curved and tapered at each end with five pale ridges (Fairbairn 1995).

All plant parts are aromatic; the seeds have an especially strong, dill-like odour. Caraway will grow wherever there is grass, over a wide range of soils and latitudes.

The chemical composition of the seeds can be affected by endogenous environmental factors. Dry and sunny weather during seed maturation reduces the oil content and induces the accumulation of carvone, while cool damp weather gives a higher yield of oil, but increases the content of limonene at the expense of carvone (Guenther 1950).

Cultivation & History

Caraway is one the oldest culinary spices and has been used to ward out evil spirits in Egyptian tombs, spice the rations of Roman soldiers and has been excavated in archaeological digs in Switzerland from 5,000 year old sites.

Caraway is native to Asia Minor and Europe, although it is now naturalized in all Canadian provinces and the Northern U.S. Cultivation now occurs over a wide range of climates and areas; Manitoba, Saskatchewan, Alberta, Holland, Poland, Russia, Egypt, the US, Jamaica and others. Caraway oil is primarily produced in the Netherlands and much of the world's production of caraway is processed and remarketed by Dutch firms, thus Holland effectively controls the supply and price of caraway (Fairbairn 1995).

Selection following introduction into cultivation has resulted in distinct differences of some agronomical features of the caraway plant which were of much benefit to field cultivation. Such features include an increased height of the plant, an erect rosette leaf growth, larger and heavier seeds with better germination (Galambosi 1996).

According to the 1999 Saskatchewan Seed Guide, seedlings are small, slow to develop and of poor competition to weeds. The crop is usually swathed because of its indeterminate growth habit and seed shattering. Nonetheless, in 1998 Saskatchewan produced 4.6 million pounds (2,100 tonnes) with 86,000 acres harvested (SCR). Plants are very sensitive to root disturbance and should not be transplanted.

Caraway can be grown successfully on a wide range of soil, although shallow and sandy soil should be avoided. In Saskatchewan, caraway has not been successful in the southwest. Its pH range is 5.8-7.5. For further agronomic and cultivation details, please refer to "The Grower's Guide to Herbs and Spices" (Fairbairn 1995) or the Saskatchewan Agriculture & Food Guide "Caraway in Saskatchewan".

Products & Uses

• Food & Cosmetic Applications

Nutritionally, caraway (fruits or oil) is widely used in flavouring food products such as bread, meat, cheese, pickles and sauces. Caraway seeds are high in both protein and fat (Holtom *et al.* 1979). Carvone has a warm, herbaceous, bread-like, spicy and slightly floral odour and a warm, sweet and spicy-herbaceous taste (Fairbairn 1995). It is an ingredient in several alcoholic beverages including the german liqueur Kummel, schnapps and gin.

The fleshy root is a delicious vegetable and can be eaten like parsnips while the young leaves are added to salads and soups to provide an aromatic tang (Bunney 1992). The young leaves are much less spicy than the seeds and have a mild parsley-dill flavour (PFAF). Older leaves can be cooked as a spinach.

Caraway oil is also used in liqueurs and soups, but its usage has been extended to mouthwashes, toothpastes, chewing gum and perfumes. An inferior quality oil, caraway chaff oil, can be obtained from the plant husks and stalks and used for scenting soups. Dried whole or ground seed are widely available commercially.

The exhausted seed, after the distillation of the oil, contains a high percentage of protein and fat and can be used as a cattle food (Grieve 1992).

• Medicinal Properties

Caraway also has a long history of use as a household remedy especially in the treatment of digestive complaints (indigestion, colic, nausea). Other medicinal properties include anti-spasmodic, carminative, expectorant and galactagogue. The oil has antibacterial activity against a number of microorganisms (including *E.coli*, *Staphalococcus aureus* and *Salmonella*

enteriditis) (Hamon *et al.* 1985) and has been shown to have marked fungicidal activity (Bisset 1994). Its utilization as a medicinal is more pronounced in Europe than in North America. A search of the internet reveals that most sites dedicated to caraway are German.

Anti-asthmatic

Among its various attributed therapeutic uses, caraway is thought to have anti-asthmatic properties and in fact, various caraway preparations (aqueous extract, macerated extract and essential oil) have been found to have bronchodilatory and anticholinergic effects on isolated guinea pig tracheal chains (Boskabady *et al.* 1998). These were not as pronounced as the bronchodilator drug theophylline, but were nevertheless significantly higher than a saline control.

Anti-carcinogenic

Some research has also suggested that caraway oil may help prevent cancer. Induction of the detoxifying liver enzyme glutathione-S-transferase (GST) is believed to be a major defense mechanism for carcinogen detoxification, thus any compound that induces an increase in the activity of this enzyme may be considered a potential cancer preventative. In 1992, Zheng *et al.* found that carvone, a major constituent of caraway oil, increased glutathione significantly in the lung, colon and small intestinal mucosa.

In 1995, incorporation of caraway into rat diets two weeks prior to chemical tumourigenesis inhibited tumour formation in mammary tissue (Shwaireb *et al.* 1995). Caraway supplementation significantly decreased the number of rats that developed tumours and in those that did, there was a significant reduction in the number of tumours. Furthermore, caraway also significantly increased the latency period of tumour appearance.

• Additional Uses

Carvone has also been reported to have some preservative activity. Pure carvone was reported to inhibit sprouting of potatoes during storage (Oosterhaven *et al.* 1992) and thus has application as an antigerminator.

Caraway is a component of gastrointestinal remedies (carminatives, laxatives) in the form of alcoholic distillates and drops, often together with other drugs containing essential oils, such as aniseed, coriander, fennel, etc. (Bissett

1994). As listed in the British Herbal Pharmacopoeia, it is used with Agrimonia, Myrica and Quercus for diarrhea and with Lobelia, Euphorbia and Grindelia for bronchitis and bronchitic asthma.

The caraway oil market shows some potential for high requirements for industrial use. The industrial market is dominated at present by synthetic derivatives.

Chemical Characteristics

Constituents

Caraway seed composition (from Bisset 1994, Fehr 1980, Formacek et al. 1982 & Lawrence 1980):

- ♦ 3-7% essential oil
 - carvone: 43.4-47.1%
-the main odiferous compound
 - limonene: 49.8-53.9%
 - carveol: 0.2 - 0.7%
 - dihydrocarveol: 0.6 - 1.2%
 - dihydrocarvone: 0.2 - 0.6%
 - myrcene: 0.4-0.6%
 - sabinene 0.10%
 - trace amounts of thujene, pinene, camphene, octanal, nonanal, linalool, neodihydrocarveol + germacrene D, terpinene, phellandrene, terpinolene, cymene, terpinen-4-ol, 3-carene
- ♦ 10-18% fixed oil
- ♦ 20% protein
- ♦ 20% carbohydrates
- ♦ fatty acids, resins, tannins (Chiej 1988)
- ♦ coumarins including umbelligerone, scopoletin and herniarin (Hamon et al. 1985)

The carvone/limonene ratio has been used to evaluate the quality of caraway oil; a high ratio meaning a high quality of oil (Galambosi 1996). Reportedly, grown caraway loses up to 2-8% of essential oil when in storage for a year (Fehr 1980). Storage was not found to have any change in component composition.

Composition of fresh caraway herb and seed (PFAF):

Constituent	Fresh Weight	
	Leaf	Seed
• Water	7.2 g	9.9 g
• Calories	253	333
• Protein	20 g	19.8 g

• Fat	4.4 g	14.6 g
• Carbohydrate	55.8 g	49.9 g
• Fibre	11.9 g	12.6 g
• Ash	12.6 g	5.9 g
• Calcium	1784 mg	689 mg
• Phosphorus	543 mg	568 mg
• Iron	48.8 mg	16.2 mg
• Magnesium	451 mg	258 mg
• Sodium	208 mg	17 mg
• Potassium	3308 mg	1351 mg
• Zinc	3.3 mg	5.5 mg
• Vitamin A	n/a	363 IU
• Vitamin B6	1.5 IU	n/a
• Thiamine	0.42 mg	0.38 mg
• Riboflavin	0.28 mg	0.38 mg
• Niacin	2.8 mg	3.6 mg

Toxicity

Large doses of caraway are reportedly harmful to the liver and kidneys (Bunney 1992). As well, the volatile oil is a mucous-membrane irritant while carvone (a ketone) and limonene (a terpene) can cause contact dermatitis (Simon et al. 1984). However, a 4% solution in petrolatum produced no irritation when applied for forty-eight hours to human volunteers in a closed patch test (Hamon et al. 1985). As well, although there were low level phototoxic effects noted, they were not considered significant and no other sensitization occurred in the twenty-five patients studied.

Caraway is said to contain the alleged 'psychotroph' myristicine (Duke et al. 1990). No known contraindications are listed by the German Commission E monograph (Bissett 1994).

Extracts

Water extraction of ground caraway seed produced an opaque, yellow-orange (bronze) extract with a strong smell reminiscent of dill and/or curry; a very spicy, aromatic smell. It was easily filtered and had an extractive yield of 11.9%. Dried solids are a light, crystalline bronze solid.

Alcohol extraction yielded a clear light yellow extract (much resembling apple juice) with an extractive yield of 9.6%. Solids consist of a dark yellow-brown, thick and viscous oil with a deep, spicy, sugary smell.

Patents

There are many patents for caraway including many various utilizations of its chemical components.

- ❖ 00517836/EP B1 (99/09/22) & 09742964 (97/11/20) Eliaz et al. US

Method and product for promoting hair growth and treading skin condition; containing tincture/extract of caraway.

- ❖ 05902622 (99/05/11) Owusu-Ansah et al. CANADA (Saskatoon)

Natural heat stable flavourings for bakery applications.

- ❖ CA2239811 (99/01/24) Beckett S.T. SWITZERLAND

Low-fat chocolate.

- ❖ 5811123 (98/09/22) Galat A.
- Natural laxative based on edible parts of caraway plant.

- ❖ CA2210435 (98/01/17) Kikuchi et al. JAPAN

Swine feed.

- ❖ CA2188972 (98/01/22) Coffey et al. US
- Lubricant for musical instrument including limonene.

- ❖ CA2217973 (97/08/21) Radwan et al.
- Environmentally-friendly, controlled-release insect repellent devise.

- ❖ 5422100 (95/06/06) Eliaz et al.
- Hair restoration, hair promotion, remelanization using essential oil of caraway and/or other plants.

- ❖ CA2128496 (95/01/22) Katsumi et al. JAPAN

Method for improving meat and fat obtained from livestock and poultry.

- ❖ CA1328821 (94/04/26) Ploeger et al. GERMANY

Anti-microbial, flavoured compositions having particular utility as a mouthwash.

- ❖ CA132485 (93/11/16) Josephson D.B. US
- Process for masking a cooked flavour in heated milk; utilizing an effective amount of caraway.

- ❖ CA2068039 (93/06/28) Yuri et al. JAPAN

Repellent for use against Ixodides utilizing linalool, limonene and essential oils composed mainly thereof caraway and others.

- ❖ CA2050089 (92/03/01) Hirose et al. JAPAN

Composition for use in oral cavity.

- ❖ CA2041702 (91/05/04) Hussein et al. US
- Flavour enhancing and medicinal taste masking agent.

- ❖ CA2041703 (91/11/04) Oppenheimer et al. US

Flavour enhancing and increased efficacy of cough drops.

- ❖ 00411205/EP A2 (91/02/06) Nagy I. HUNGARY

Composition, primarily for anticorrosive and insulating coating.

- ❖ 62273909 JP (87/11/28) Minosasa et al. JAPAN

Agent for nourishing and growing hair utilizing carvone for purified caraway seed oil.

- ❖ CA 1210271 (86/08/26) Spiel A. US
- Rye flavouring with caraway as a component..

- ❖ CA1142025 (81/02/27) Todd et al. US
- Liquid seasoning compounds II.

Cost & Availability

Plant part: seed only, aerals in bloom (baled)

Sask. Availability: This crop has been successfully grown in Saskatchewan for at least ten years. Both biennial and annual caraway are grown, but the biennial is more common due to its more rapid seed maturation and ease of establishment with a nurse crop. Both certified organic and conventional caraway seed/bales are available in Saskatchewan.

Sask. Price:

Conventional seed

Grower Direct, bin-run: \$0.66-\$0.75/kg

Dealer's Price, clean: \$1.00-\$1.15/kg

Conventional Aerals in bloom (baled)

Grower Direct, 90% pure: \$350-\$500/tonne

Certified Organic Seed

Grower Direct, bin-run: \$2.20-\$2.50/kg

Dealer's Price, clean: \$3.50-\$4.25/kg

Certified Organic Aerals in bloom (baled)

Grower Direct, 90% pure: \$600-\$900/tonne

Potential Suppliers:

Conventional

♦ Schweitzer Enterprises, Eston Sask.

(306) 962-4751

♦ Dandilee Agro, Gerald Sask.

(306) 745-2510

Certified Organic

♦ Ian Cushon, Oxbow Sask.

(306) 483-5034

Recommended Resources:

M Fairbairn C. 1995. The grower's guide to herbs and spices. University Extension Press. University of Saskatchewan, Saskatoon.

- an excellent resource for marketing, adaptation, soil preparation, harvesting and processing information

M McVicar R. et al. Caraway in Saskatchewan. FarmFacts. Saskatchewan Agriculture and Food.

- an agronomic guide to the production of caraway in Saskatchewan

Comfrey

Symphytum officinale (L.)

Family: Boraginaceae

Common names: Blackwort, Boneset, Bruisewort, Gum plant, Salsify, Slippery root, Knitback, Consound, Ass ear, Nipbone, Consolida

Scientific pseudonyms: none found

Comfrey has a wide and diverse reputation. Since it was found that rats with comfrey-supplemented diets developed cancerous tumours, comfrey has been legally banned from internal use. However, has the classical and beneficial pharmacology of pyrrolizidine alkaloids been overshadowed by the well-recognized toxicity of this class of compounds? (Newall et al. 1996). The wondrous medicinal properties of this plant have scarce been disputed in its thousands of years of use, but recently, its safety has. Much misinformation surrounds the toxicity of this plant, which is considered safe in moderation and for external use. James A. Duke deems a cup of comfrey leaf tea less carcinogenic than a beer or even a diet cola. Is comfrey worth another cautious look?

Description & Habitat

Comfrey is a hardy perennial herb native to Eurasia which has been introduced and naturalized in many parts of Canada, especially on damp roadsides and waste places. Anchored by a black, tuber-shaped root, it is supported by a square, hairy stem and adorned with thick, lanceolate leaves which decrease in size toward to top of the stem. The lower leaves are alternate and stalked; those higher up the stem are narrower and their bases continue as wings down the stem to the leaf below (Bunney 1992). Comfrey has one of the highest biomass yields of all herbs (Miller 1998), producing large amounts of foliage from late May until hard frost in autumn (Teynor et al. 1992).

The 2-3 foot herb produces terminal flower cluster comprised of bell-shaped white, purple or pink flowers from June to August. The fruit consists of 4 ovoid, glossy-black nutlets (Bunney 1992). The thick black root forms a deep and expansive root system. It is highly mucilaginous with a pale-coloured cortex, tasting somewhat sweetish and slightly astringent (Hamon et al. 1985). The reported life zone of comfrey is 6-25°C with an annual precipitation of 50-270 cm and a preferred soil pH range of 5.3-8.7 (Simon et al. 1984).

There are two kinds of comfrey in usage; common comfrey (*Symphytum officinale*) and Russian comfrey (*Symphytum X uplandicum* Nyman or *Symphytum peregrinum* Ledeb.). Russian comfrey is the result of a cross between common comfrey and prickly comfrey (*Symphytum asperum*). While Russian comfrey has been stated to grow larger and faster in Saskatchewan, it contains more of the pyrrolizidine alkaloids, echimidine and symphytine (Abbott 1988).

Cultivation & History

Comfrey has been cultivated since about 400BC as a healing herb when Greek and Roman doctors utilized comfrey to stop heavy bleeding, treat bronchial problems, heal wounds and broken bones (Teynor et al. 1992). It is native to Eurasia and extends throughout most of Europe into central Asia and western Siberia. It was introduced to Canada by settlers and is now naturalized in many parts of the country. Current world production is centred in Brazil and Argentina, with limited production in the United States.

Comfrey has several characteristics which make it an extremely hardy crop (Teynor et al. 1992):

- resistance to wilting due to its deep, extensive rooting system
- grows very quickly and is tolerant of being cut several times a year
- excellent weed competitor due to rapid and dense growth
- has few insect pests and is usually grown without herbicides
- can thrive in any soil or situation, especially in shade
- is very frost-resistant

Seed production is rare and crops are usually established from root cuttings and crown divisions. As described by Teynor *et al.* (1992), production during the first year is greatest for a crop started from transplants and lowest for one using root cuttings. Following the first year, however, comfrey yields are the same regardless of propagation method.

Comfrey is primarily propagated from rootstock (Miller 1998). Roots from an older field are quartered and cut by hand. Root cuttings are usually 1.5-6 inches long and ½ inch in diameter. Smaller cuttings will also generate plants, but longer cuttings emerge and establish more quickly. Roots are very brittle and the least bit of root will start a new plant. They are then planted 4 inches deep and in rows one foot apart. Root cuttings develop buds about 3-6 weeks after planting, while crown divisions emerge in approximately 10 days.

Vegetative growth does not cease with the start of flowering and the plant will add new stems continuously during the growing season. Comfrey will grow rapidly and flower again following harvest.

It is recommended that comfrey be cut before 10% of the crop goes to flower. Comfrey cannot be sun-dried due to its high mucilage content. The best method of harvest is to cut it at 6 inches from the ground with a side-bar cutter (Gunner 1998). Leaves can be harvested up to four times a season, although care should be taken not to bruise the leaves as it causes them to darken. Herb yields can reach five tonnes/acre (four cuttings) dry weight for an established planting (Gunner 1998).

Root harvest can be done with potato or ginseng digging equipment (Gunner 1998). Dry root yields vary from 5 to 12 tonnes/acre. Comfrey plantings can last indefinitely (over 20 years) given proper weed and soil fertility maintenance. Comfrey can also be used to provide "instant compost" for crops such as potatoes.

Products & Uses

• Food Uses

Although long grown for medicinal and nutritional properties, comfrey is sometimes used as an ornamental and culinary herb. Fresh leaves are used as a salad green because it is a good source protein and a rare plant-derived source of vitamin B₁₂, although one

would have to consume an inadvisable 4 lbs a day to meet the minimum daily requirement (Teynor *et al.* 1992). Comfrey protein content of dry matter (15-30%) is about as high as legumes but is lower in eight essential amino acids.

The dried or roasted roots can be combined with dandelion and chicory for use as a non-cafeinated coffee (Simon *et al.* 1984), while a tea can be made from its dried roots and leaves. Young shoots can be used as an asparagus substitute while leaves can be added to salads and roots to soup.

• Cosmetic Applications

Comfrey is one of the most useful botanicals that can be employed in cosmetics (Mascolo *et al.* 1987). It is an ingredient in various herbal, pharmaceutical and cosmetic preparations (Duke 1985).

It has certain traits of benefit for utilization in cosmetics: it provides moisture for dryness of the skin, promotes tissue repair, creates astringency and reduces inflammation and clotting. It is good for use in burn creams, lotions, salves, douches, hair rinses, shampoos, eyedrops, massage and body oils (D'Amelio 1999). It combines well with *Ulmus fulva*, *Fillipendula*, *althea*, *aloe* and *cone flower*.

Comfrey can also be found in soap bars; a white comfrey and cucumber biodegradable soap is available in local health stores.

• Medicinal Uses

In the British Herbal Pharmacopoeia published by the British Herbal Medicine Association, comfrey leaf and root are both listed for indications of gastric and duodenal ulcer. Comfrey root and leaf are also recommended as a poultice for external wounds including bruises, sprains, fractures, mastitis and athlete's foot. The German Commission E monograph lists comfrey for external use for contusions, sprains and dislocations. It warns that the drug should only be applied to intact skin and for no longer than 4-6 weeks a year, but it does not list any known side effects or contraindications.

Comfrey contains allantoin which is found in milk of nursing mothers and fetal allantoin affects the rate of cell multiplication by promoting proliferation which speeds up the

healing process. An effective allantoin formulation is difficult to prepare from comfrey, however, due to the low and variable content of this substance (Teynor *et al.* 1992). Several comfrey constituents are also known to possess antibacterial and anti-inflammatory properties including rosmarinic, p-coumaric, salicylic and caffeic acid (Grabias *et al.* 1998).

Comfrey is locally available in manufactured products such as creams and gels for treatment of external wounds and bruises. Dried, bulk comfrey leaves and root are also available in small quantities at local health and herb stores, as well as tinctures, teas, and tablets. The illustrated comfrey gel product is from Sun Soap, which specializes in comfrey products (www.merchantmall.com/stores/sunsoap).

• **Assorted Others**

Comfrey has also been used as a fodder crop for livestock (Simon *et al.* 1984), although this use is somewhat restricted by its low palatability (Teynor *et al.* 1992). Pigs, sheep and poultry, will nevertheless eat fresh comfrey leaves although cattle and rabbits tend to stay away. Cattle will, however, eat the wilted forage.

Recent studies indicate that a 60% and 40% alfalfa/comfrey pellet might have excellent export opportunities as a cattle food (Miller 1998). This mixture of dehydrated comfrey and green alfalfa extruded into a pellet or cube constitutes a "whole food" for cattle.

Chemical Characteristics

Constituents (Newall *et al.* 1996)

- **Alkaloids (Pyrrolizidine-type):** 0.3% - Symphytine, symylanlandine, echimidine, intermidine, lycopsamine, myoscorpine, acetyllycopsamine, acetylintermidine, lasiocarpine, heliosupine, viridiflorine, echiumine

-Fresh leaves of Russian comfrey contain 24% echimidine and 32% acetyllycopsamine; (Abbott 1988)

-Roots and rhizomes have a greater concentration of pyrrolizidine alkaloids than do the leaves, with younger leaves higher in content than older ones (Hamon *et al.* 1985)

- **Carbohydrates:** Gum (arabinose, glucuronic acid, mannose, rhamnose, xylose)
Mucilage 25-30% (glucose, fructose)

- **Tannins (pyrocatechol-type):** 2.4%

- **Triterpenes:** Phytosterols (sitosterol and stigmasterol), steroidal saponins, isobauerenol

- **Others:** Allantoin (0.75-2.55%), caffeic acid, carotene (0.63%), chlorogenic acid, choline, lithospermic acid, rosmarinic acid, silicic acid.

-All plant parts of comfrey contain allantoin: dried roots contain 0.4-1.5% while dried leaves contain 0.1-1.6%

Comfrey amino acid composition, % total sample (D'Amelio 1999):

• alanine	1.20
• arginine	0.93
• aspartic acid	2.93
• cystine	0.10
• glycine	0.99
• glutamic acid	0.59
• histidine	0.47
• isoleucine	0.61
• leucine	1.65
• lysine	1.05
• methionine	0.26
• phenylalanine	0.19
• proline	0.92
• serine	0.92
• threonine	0.72
• tryptophan	0.65
• tyrosine	0.59
• valine	0.89

Comfrey vitamin composition, mg/100g (D'Amelio 1999):

• thiamin (B1)	1.0
• riboflavin (B2)	7.0
• nicotinic acid	5.0
• pantothenic acid	4.2
• Vitamin B12	0.07
• Vitamin C	100
• Vitamin E	30
• allantoin	0.18

Dried comfrey feed analysis (D'Amelio 1999):

• protein	30.3%
• crude fat	1.01%
• crude fiber	14.1%
• ash	25.7%
• N-free extract	28.9%
• total digestible nutrient	49.3%
• calcium	1.6%

• phosphorus	0.79%
• magnesium	0.62%
• potassium	8.2%
• sodium	0.48%
• sulfur	0.21%
• manganese	100 ppm
• copper	15 ppm
• cobalt	3.8 ppm
• zinc	44 ppm
• iron	1200 ppm
• molybdenum	0.30 ppm

Content of phenolic acids in comfrey herb and root; mg/100g dry weight (Grabias *et al.* 1998):

	<i>Herb</i>	<i>Roots</i>
• rosmarinic	620	160
• caffeic	13.2	1.02
• m-hydroxybenzoic	1.52	4.47
• salicylic	0.01	1.80
• p-coumaric	1.52	0.20
• gentisic	n/a	0.65
• protocatechuic	0.54	n/a
• ferulic	0.81	0.6
• benzoic	0.174	n/a
• p-hydroxyphenyl-acetic	0.147	n/a
• isovanillic	0.124	n/a
• additional herb phenolic acids (<0.06) include: cinnamic, vanillic, gamma-resorcylic, b-resorcylic, syringic and sinapic		
• additional root phenolic acids (<0.02) include: cinnamic, p-hydroxybenzoic, vanillic, homoveratric, homoprotocatechuic, m-coumaric and isoferulic		

There are a total of 19 phenolic acids plus cinnamic acid in the herbs and root of common comfrey (Grabias *et al.* 1998).

In comfrey, largest alkaloid concentrations are found in the roots (0.07%), with leaves containing higher quantities of the alkaloid as they grow older (0.062%) and young leaves contain almost none (0.006%). Some commercial products of roots and leaves sold as herbal teas and medicinal preparations have total alkaloidal concentrations of 270 mg/kg in leaves and 2900 mg/kg in the roots (Hamon *et al.* 1985).

Toxicology

The obvious problem with this herb rests in its pyrrolizidine alkaloid content and the reported necrotic and carcinogenic effects of these compounds. Alkaloids are widely distributed

compounds in the plant kingdom, mainly among the higher plants, and are recognized to be hepatotoxic, pneumotoxic, carcinogenic and mutagenic (Figueriredo *et al.* 1997). It is not the pyrrolizidine alkaloids themselves which are toxic but their metabolites; research from animal studies suggest that they are absorbed extensively from the gastrointestinal tract followed by metabolism in the liver (Abbott 1988).

A typical cup of comfrey tea contains 8.5 mg of alkaloids and the ingestion of some of the gelatinous residue increases this amount to 26 mg per cup (Hamon *et al.* 1985). It is estimated that habitual ingestion of comfrey tea four to thirteen times this potency or the very frequent ingestion may produce serious problems in human health (Hamon *et al.* 1985). Ingesting pyrrolizidine alkaloids for several months can reportedly lead to veno-occlusive problems and severe portal hypertension, which can progress to cirrhosis of the liver and death (CPPI).

The major finding that thwarted the use of this herb came in 1978 when it was reported that rats fed a diet supplemented with comfrey developed cancerous tumours. Since then, several aspects of the experimental procedure have been criticized including the young age of the test subjects, the amount of comfrey fed and the actual species of comfrey utilized.

Yet despite the carcinogenesis revealed in animal study, there are no reported cases of cancer in humans that have arisen as a result of the ingestion of comfrey - or, indeed, of any other source of pyrrolizidine alkaloids (Abbott 1988). While there can be little doubt that the excessive consumption of pyrrolizidine alkaloids (either as a single high dose or as multiple moderate doses) can be harmful, there are a number of reasons why the risk of cancer from the use of comfrey, particularly herbal preparations, will be low (as described by Abbott 1988):

- first, there is the evidence of animal studies to suggest that pyrrolizidine alkaloids are, at best, weak carcinogens that produce liver tumours at only a relatively low incidence after high-dose exposure
- the incidence of human liver cancer is low even in population where the use of herbal medicines is widespread

Problems associated with the chronic ingestion of comfrey have been readily recorded, however, and there is consistent disease etiology. Two reports of human hepatotoxicity associated with the ingestion of comfrey have been documented: a 13-year old boy given a root preparation to treat Crohn's disease and a 49-year old woman whom it was estimated ingested 15ug/kg body weight/day over a six-month period (Newall *et al.* 1996). Both developed veno-occlusive disease, the result of chronic toxicity characterized by the presence of greatly enlarged liver cells.

However, evidence of the effects of comfrey are still not completely elucidated, as illustrated in the following table (Tierra 1992):

*Dr. Duke's BURP (Better Understanding of Relative Potencies) indices of some beverages (adapted from Ames *et al.* and Ames & Gold):*

BURP Index	Beverage	Estimate based only on
1	Tap water	chloroform
10	Apple juice	1,1dimethylhydrazine
25	Beer ¹	dimethylnitrosamine
125	Comfrey leaf tea	symphyline
175	Diet cola	saccharin
575	Root beer ²	sairole
850	Basil tea	estragole
7700	Cola	formaldehyde
8000	Beer (modern)	ethanol
18000	Wine	ethanol

1 - before 1979

2 - old fashioned

In a study of the liver function of 29 chronic comfrey users, no abnormalities were detected (Anderson *et al.* 1989). Although the risk to humans of acute liver necrosis as a result of the moderate consumption of comfrey appears to be very low, at present it is not possible to determine a "safe" level of long-term exposure to avoid veno-occlusive disease (Abbott 1988).

While positive results for mutagenicity have been obtained for a range of pyrrolizidine alkaloids in mammalian culture cells (Bull *et al.* 1968), there has been a reported lack of mutagenic activity for comfrey following assessment using direct bacterial test systems (Ames), host mediated assay (Legator), liver microsomal assay and the micronucleus technique (Newall *et al.* 1996).

From the data that are available, Abbott (1988) concluded that the potential exists for pyrrolizidine alkaloid-induced liver toxicity after long-term exposure, albeit with mild effects, even at modest levels of intake. There is sufficient concern to justify restricted intake.

Externally, the use of comfrey is not nearly as hazardous since these pyrrolizidine alkaloids must undergo metabolic transformation in liver tissue to become active carcinogens (Hamon *et al.* 1985). Topical herbal preparations are not considered toxic because the alkaloids do not reach the liver (Huxtable 1989) and percutaneous absorption of pyrrolizidine alkaloids present in comfrey is reported to be low (although application of comfrey preparations to the broken skin should be avoided) (Newall *et al.* 1996).

Comfrey is listed by the Council of Europe as a natural source of food flavouring which although permitted for use as a food flavouring, insufficient data are available to assess toxicity (Newall *et al.* 1996). In Canada, it appears that many products on the market labeled "comfrey" or "common comfrey" contain echimidine (considered to be the most toxic of the comfrey pyrrolizidine alkaloids) and must therefore have come from Russian comfrey (Bissett 1994). Its sale for human consumption is banned in Canada.

Extracts

Water extraction of dried, ground comfrey leaves and stems produced an extraordinary sludge of a thick, viscous and highly gelatinous material. Only a very small quantity of extract filtered through cheesecloth, while the remainder had to be thoroughly rediluted with distilled water to allow filtration. The resultant extract was brown, very gelatinous with an unpleasant odour and an extractive yield of 28.9%. If there is any value in this extract, its consistency is certainly a consideration. The extract solids appear a bronze-maroon colour and consist of a crystalline very-fine powder.

Ethanol extraction was entirely different. Extraction was a very standard procedure with yield of a very dark, clear green extract with an extractive yield of 37.9%. Residual plant material was a fine, yellowish-green powder and the solids a very dark green, gummy and malleable solid with a non-oily and non-sticky feel. It has a pleasant hay smell.

Patents

The following patents exist for comfrey:

- ❖ 5958418 (99/09/28) Johnson-Prillerman K.O.
External herbal composition for treating muscle aches and joint pain; a herbal mixture.
- ❖ 09913892 (99/03/25) Jauregui-Renault M. MEXICO
Antimastitic pharmaceutical composition and preparation process.
- ❖ 10306030 JP (98/11/17) Manabe E.
External preparation composition; alleviates cutaneous irritation by use of antiphlogistics and analgesics.
- ❖ 10286075 JP (98/10/27) Nishimura H. JAPAN
Deodorant of *S. officinale*, production of deodorant and food using deodorant of *S. officinale*.
- ❖ 10265347 (98/10/06) Takoka et al. JAPAN
Agent for extending hair growth period.
- ❖ 10182335 JP (98/07/07) Mori et al. JAPAN
Antimicrobial and low-irritation cosmetic.
- ❖ 05702691 (97/12/30) Ichinose et al. JAPAN
Flavonol derivatives and hair-nourishing, hair-growing compositions containing the derivatives.
- ❖ 09241131 JP (97/09/16) Tezuka et al. JAPAN
Hair tonic.
- ❖ 96165227 (96/06/25) Nishibe et al. JAPAN
Hair dyes containing p-phenylendiamine derivatives and *S. officinale* leaf extracts to control phenylendiamine related dermatitis.
- ❖ 07278001 JP (95/10/24) Nishibe et al. JAPAN
External preparation for skin and bathing agent; new antiallergic.
- ❖ CA1298134 (92/03/31) Harima S. JAPAN
Health food; to avoid harmful effects of smoking.
- ❖ 5028429 (91/07/02) Gochenouer C.J.
Leg blister; a mix for use on horses.

- ❖ 00293498/EP A1 (88/12/07) Noorlander D.O.

Nontoxic, germicide and healing composition; comprised of *S. officinale* extract and other compounds.

- ❖ CA1189738 (85/07/02) Shimazu T. JAPAN

Nourishing food and method of producing the same; efficacious versus alopecia and blood pressure trouble.

- ❖ 4258035 (81/03/24) Spies J.A.
Method and compound for treatment of arthritic conditions in dogs; a herbal mix.

Cost & Availability

Plant part: root only, aerals

Sask. Availability: Only one of the numerous growers appearing in the Saskatchewan Herb and Spice Association's "Member and Resource Guide" listed comfrey as a crop under cultivation. She only had a few plants. This botanical does thrive in our climate and could easily be produced here in large volumes.

Note: Health Canada lists comfrey as a restricted plant. Its sale for human consumption is presently banned in Canada.

Sask. Prices: n/a

Prices Outside Sask.:

Root, whole or milled: \$10-\$14/kg US
Aerials, milled leaf: \$10-\$12/kg US

Potential Suppliers:

- ♦ Wild Botanicals, Murphy Oregon, USA (541) 846-6395
- ♦ Pacific Botanicals, Grant's Pass Oregon, USA (541) 479-7777
- ♦ Trout Lake Farm, Washington State USA (509) 395-2025

Recommended Resources:

M Teynor et al. 1992. Comfrey. NewCROP: New Crop Resource Online Program. Centre for New Crops and Plant Products. Purdue University.

(<http://www.hort.purdue.edu/newcrop/>)

- provides information of the history, uses, growth habit and detailed cultivation

information including harvesting, drying and storage, pest and weed control as well as planting information

M Figueiredo et al. 1997. Pyrrolizidine alkaloids: A word of caution. *Clencia e Cultura Journal of the Brazilian Association for the Advancement of Science* **49(5/6)**: 331-338.

- A thorough discourse on pyrrolizidine alkaloids; useful to acquire a good understanding of the chemistry, structure and toxicity of these compounds although may prove a bit advanced for non-chemists

M Abbott P.J. 1988. Comfrey: assessing the low-dose health risk. *The Medical Journal of Australia* **149**: 678-682.

- A highly recommended review of the controversy and health risks of comfrey: for anyone interested in the clinical aspects and risks based on medical fact.

Coriander

Coriandrum sativum L.

Family: Umbelliferae (Apiaceae)

Common names: Chinese parsley, Cilantro

Scientific pseudonyms: none found

Coriander is a spice crop whose cultivation is well-established in Saskatchewan. Much of this production, however, is exported to larger centres for use in the spice industry and little processing occurs in the province. Given several marked functional activities, there exists many other opportunities for this crop in the nutraceutical and therapeutic markets. Recent research has shown that an aqueous extract of coriander represents a possible antihyperglycaemic dietary adjunct and potential source of a new orally active agent for diabetes therapy (Gray et al. 1999). As well, a variety of coriander herb oils with different odour and flavour are available by simple post-harvest treatments.

Description & Habitat

Coriander is an annual, erect herb with a furrowed solid branched stem which usually grows to a height of two feet (Bunney 1992). The lower leaves are broad leaflets while the upper leaves are finely divided. Roots are slender and highly branched (Luayza et al. 1990).

Flowers are produced in white or pink-petal led compound umbels in July and August and are highly attractive to pollinating insects. Fruit are nearly globular, reddish-brown double achenes consisting of two single-seeded mercurers.

The unripe plant and seed have a strong, fetid "bugged" smell from whence the Greeks derived its name (Kooris = bug). The smell in the unripe fruit and herb is due to the predominant aliphatic aldehydes present in the volatile oil. Upon ripening, the fruits acquire a more pleasant and sweet odour as the major sweet odour as the major constituent of the volatile oil becomes the monoterpene alcohol linalool. The reported life zone of coriander is 7-27°C with an

annual precipitation of 0.3-2.6 m and a soil pH of 4.9-8.3 (optimum of 9.3); it thrives in full sun and deep fertile loams (Simon et al. 1984).

Two types of coriander are grown in Saskatchewan, production mainly delimited by the length of the growing season. The main production is of the large-seeded type (variety *macrocarpum* with a fruit diameter of 3-5 mm) which has an oil content of 0.5-1% and takes about 100 days to harvest. This type is also grown mainly in tropical and subtropical countries and are used extensively for grinding and blending purposes in the spice trade (Smallfield 1993). The small-seeded variety (variety *microcarpum* with a fruit diameter of 1.5-3 mm) has a higher oil content (1-1.5%) but takes an added 20 days to harvest. This type is usually produced in temperate regions and, having a higher volatile oil content, is highly valued as a raw material for the preparation of essential oil (Smallfield 1993).

Cultivation & History

Coriander is native to the eastern Mediterranean region, southern Europe and India where it has been cultivated as a medicinal plant for 3,000 years. In Saskatchewan, 1998 production yielded 10,900 tonnes of coriander seed which was harvested from 29,500 acres, a considerable increase from the 1997 production of 5,300 tonnes (SCR). Coriander is also produced in China, Bangladesh, Indonesia, Poland, Syria and Mexico, although Canada's main competitors in the export business are Morocco, Romania, Bulgaria, Argentina and India.

Dr. Stan Blade, Director of Alberta's Crop Development Centre North, describes coriander as being a good potential crop as demand in Canada and the US is increasing due to growth in consumption of ethnic foods and processed meats. In 1992, a net income of \$58.05/acre was achieved in Saskatchewan; compared to \$25.32 for canola and \$10.34 for wheat (Blade 1999). Coriander remains a risky crop, however, as it is ineligible for major grain subsidy programs and insurance is very expensive.

Coriander germinates very slowly, a process which may take as long as 21 days. Therefore, like its fellow family member caraway, coriander seedlings do not compete well with weeds necessitating proper weed control during crop establishment. The plant has also been known

to benefit from pollination by bees (Fairbairn 1995).

Coriander is a heat-tolerant crop which can grow on a variety of soils, preferably well-drained loam and sandy-loam soils. It is always propagated from seed which should be sown in late April to mid-May. Seed yield can be affected by a variety of environmental factors:

- research has indicated that higher seed yields and oil levels can be achieved by seeding earlier than May 20 (McVicar *et al.* 1996)
- application of vermicompost significantly increases herbage and seed yield and is comparable to applying chemical fertilizers (Vadiraj *et al.* 1998).
- despite its propensity for hot weather, flower blast can occur if very hot and dry conditions prevail during its bloom, effectively and significantly lowering seed yield.

Researchers from the University of Saskatchewan grew a variety of large-seeded coriander (Richters-Long, Chinese, Autumn, ND-1, Roumain and Richters 93) and small seeded coriander (PGR-5741, Saskatoon Early, PGR-10056, PGR-5742 and PGR-10057) at several locations in western Canada over a two-year period in 1994-1996 (refer to Arganosa *et al.* 1998). Their results showed that although the large-seeded varieties had a higher seed weight (9.2-9.9 g), the small-seeded varieties had both higher essential oil content (1.22-1.3%) and linalool content (63.9-66.2%). Large-seeded cultivars produced essential oil content of 0.83-0.9% and linalool content of 60.7-62.5%. The yield of essential oil averaged 20 litres/ha with oil content and yield proving highest when the crop was irrigated and cultivated early.

Products & Uses

• Food Uses

The coriander plant yields two primary products that are used for flavouring purposes: the fresh green herb cilantro and the seed spice known simply as coriander seed (Smallfield 1993). Coriander seeds, whole or ground, are used primarily as a flavouring agent in the food industry or as spice for breads, cheeses, curry, fish, meats, sauces, soups, pastries and confections. They are also used to flavour alcoholic beverages including gin and liqueurs

and to cover the taste or correct the nauseating qualities of medicines (Smallfield 1993).

In England, coriander seeds are sugar-coated to make "comfits", a popular confection which later became jawbreakers in America. Fresh leaves, cilantro, are especially popular when used as a flavouring agent in soups and stews. The fruit has also long been used to flavour cigarette tobacco. After extraction of the oil or oleoresin, the remaining coriander seed can be used as a cattle feed (Su 1986).

• Essential Oil

Coriander oil is prepared by steam distillation of mature, dried and crushed fruit. The essential oil is a colourless or rather pale-yellow liquid with an aroma best described as pleasant, sweet and somewhat woody and spicy, with a floral-balsamic undertone and peppery-woody topnote as the characteristic features (Smallfield 1993). The flavour is similarly described as mild, sweet and spicy-aromatic yet somewhat warm and slightly burning.

Interestingly, simple post-harvest treatments have been shown to have dramatic and previously unreported effects on the composition and yield of coriander herb oils (Smallfield *et al.* 1994). Storage of chopped herb for 24 hours before distillation produced an oil with decan-1-ol as the major components (refer to *Constituents* sections); it has a "floral odour resembling orange flowers; slight, characteristic fatty taste" (Furia *et al.* 1975). Thus, a variety of coriander herb oils with different odour and flavour are available by simple post-harvest treatments (Smallfield *et al.* 1994).

The essential oil is used in perfumes, soaps and other cosmetics. The oil can be split into two basic types; one for use in making soaps whilst the other can be used in making plastics (PFAF). Alternatively, coriander has also been used as an aphrodisiac in the formulation of love potions, although the current market for love potions has greatly declined in the last century.

• Medicinal & Nutraceutical

Traditionally, coriander is used as an antispasmodic, carminative, stimulant and stomachic. It has exhibited significant hypoglycemic and hypolipidemic activity and has a profound influence on the metabolism of

lipids in animals fed a cholesterol containing diet (Chithra *et al.* 1997). Experiments by Gray & Flatt (1999) in the treatment of streptozotocin-diabetic mice not only confirmed the antihyperglycaemic action of coriander seed extract, but also further indicated the presence of natural products which exhibit insulin-releasing and insulin-like actions.

In addition, the essential oil exhibits a definite, but not especially strong, antimicrobial action (Hamon *et al.* 1985). Coriander is also a rich source of acetylcholine, a powerful agent which lowers the blood pressure, and methionine, considered to be an important amino acid for hair growth (Gopala Rao *et al.* 1978).

• **Insecticide**

Due to the ability to repel aphids, coriander makes a good companion plant in the garden growing especially well with dill and chervil. Coriander oil has also been evaluated as a candidate for development as a protectant for food commodities against common pest insects: it showed contact toxicity and repellency to rice weevils and confused flour beetles (Su 1986).

Chemical Characteristics

Constituents

Comparative chemical composition of coriander oil at various stages of maturity (Lawrence 1993):

Compound	1	2	3	4
octanal	1.20	0.85	0.44	0.36
nonanal	0.51	0.11	0.05	0.08
decanal	30.0	11.9	6.24	1.61
camphor	0.08	0.52	2.18	2.44
(E)-2-decenal	20.6	46.5	30.2	3.90
dodecanal	3.30	0.96	0.52	0.41
(E)-2-undecenal	2.56	1.39	-----	-----
tridecanal	3.07	20.2	1.08	0.46
(E)-2-dodecanal	7.63	5.95	4.78	2.49
tetradecanal	0.68	0.12	0.11	0.15
(E)-2-tridecenal	0.49	0.14	0.09	0.13
(E)-2-tetradecenal	4.45	1.73	1.59	1.73
linalool	0.34	17.5	40.9	60.4
geraniol	0.19	0.35	0.93	1.42
geranyl acetate	4.17	0.76	0.69	0.66

♦ Key: (1) floral initiation; (2) full flowering, primary umbel young green fruit; (3) full green fruit; (4) brown fruit on lower umbels, green fruit on upper umbels; (----) not detected

In depth analysis of coriander oil has yielded identification of 203 individual components of which only 18 comprise 97% of the total oil (Smallfield 1993). The major sensory effect of the oil comes from the 180 trace components that occur, on average, in concentrations of about 0.01% or less.

Amino acid composition of coriander seed per gram dry weight (Gopala Rao *et al.* 1978):

• leucine	12 ug
• methionine	28 ug
• threonine	12 ug
• tryptophan	14 ug
• valine	14 ug

Seed composition (various authors):

- fixed oil
- volatile oil
 - linalool (corinadiol) 65-80% (Hamon *et al.* 1985)
 - myrcene 1.71%
 - citronellol 4.64%
 - geraniol 9.29%
 - safrole 2.67%
 - geranyl acetate 18.1% (Bhattacharya *et al.* 1998)
 - alpha-pinene, limonene, gamma-terpinene, camphor (Taskinen *et al.* 1975)
- fatty oil, proteins, tannins, pectin, sugars, vitamin C (Bunney 1992)

Methionine and acetylcholine content of coriander during the vegetative and reproductive states; dry weight basis (Gopala Rao *et al.* 1978):

	Methionine (ug/g)	Acetylcholine (umole/g)
Vegetative Stage		
• root	28	58
• stem	150	92.4
• leaf	192	287
Reproductive Stage		
• root	103	171
• stem	120	148
• leaf	261	262
• pod	80	35.1
• seed	28	37.7

Fresh coriander leaf composition (PFAF):

- oxalic acid 0.012%
- calcium 0.172%
- volatile oil (Potter *et al.* 1990)
 - (E)-2-dodecenal (10%)
 - dodecanal (16%)
 - 2-decen-1-ol (9%)

- (E)-2-tetradecenal (6%)
- decanal (4%)
- decan-1-ol (4%)

Toxicology

Sensitivity studies produced no irritation from exposure to the oil after a forty-eight hour closed patch test in human volunteers and appears to be relatively non-toxic (Hamon *et al.* 1985). Linolool in coriander oil is known to cause contact dermatitis (Simon *et al.* 1984). The estimated acceptable daily intake of linolool is up to 250 micrograms per kilogram of body weight (Hamon *et al.* 1985); the plant can have a narcotic effect if it is eaten in very large quantities (PFAF).

Extracts

Water extraction of ground coriander seed yielded an opaque, reddish-orange coloured extract with an extractable yield of 13%. It has a very distinct, sweet and spicy smell. Solids are a crystalline red-brown colour with a faint odour.

Ethanol extract is a clear, very pale yellow liquid with a solids content of 20%. The solid consists of a golden orange oil with some white precipitate and a thick, deep spicy smell.

Patents

Seventeen patents are listed for coriander in CIPO with another two in US PTO. As listed below, however, the most recent patents for this plant originate mostly in Japan. There are many other patents which include coriander as one of several other plants to be utilized in a certain composition or products; these have for the most part been excluded due to their nonspecificity.

- ❖ 10265346 JP (98/10/06) Takeoka *et al.*
JAPAN

Agents for extending hair growth period.

- ❖ 10114671 JP (98/05/06) Matsukura *et al.*
JAPAN

Cell activator and its applications; prevents and improves age spots.

- ❖ 10067672 JP (98/03/10) & 05720304
(98/02/24) Omura Y. JAPAN

Method of treatment of some resistant infections, cancer and other diseases which

have infection and localized metal deposits in pathological areas.

- ❖ CA2116237 (98/01/20) Wilson W.R. US
Organic pesticide; contains coriander tincture or several others.

- ❖ 06181716 JP (94/07/05) Tanihara *et al.*
JAPAN

Method for treating *Coriandrum sativum*; immersing coriander in water and roasting in olive oil to remove bitter taste.

- ❖ CA2086361 (93/07/01) & 5260053
(93/11/09) Chappell *et al.* US
Herbal deodorant with active antibacterial constituents free of petroleum derived compounds and alcohols.

- ❖ CA2046410 (93/01/06) Plummer *et al.* US
Composition and method for discouraging spiders, insects or the like.

- ❖ 04022921 (77/05/10) Sakakibara *et al.*
JAPAN

Method of retarding oxidation of edible fat or oil in stored food; prevents oxidation by presence of small amounts of young leaves and shoots, or juice extract of coriander.

Cost & Availability

Plant part: seed

Seed Availability in Saskatchewan: Both large-seeded and small-seeded coriander are grown in Saskatchewan, often under contract to spice seed dealers. Statistics on seeded acres are sometimes reported by Saskatchewan Agriculture & Food.

Seed Price in Saskatchewan: There is currently a global surplus of coriander seed, and this is reflected by low prices.

Grower direct, bin-run: \$0.33-\$0.37/kg
Dealer's price, clean: \$0.44-\$0.53/kg

Leaf Availability in Sask.: No commercial cilantro producers were located in Sask.

Leaf Availability outside Sask.: A number of commercial herb/spice houses trade cilantro.

Potential Suppliers:

Seed

- ♦ Dandilee Agro, Gerald Sask.
(306) 745-2510

Leaf

- ♦ Starwest Botanicals, Rancho Cordova,
California USA (916) 638-8100
- ♦ Jaya International Inc. Scarborough,
Ontario (406) 335-0900

Recommended Resources

M Coriander in Saskatchewan. FarmFacts.
Saskatchewan Agriculture and Food. Website:
(<http://www.agr.gov.sk.ca/>)

- provides all the necessary agronomics to
grow coriander in Saskatchewan

M Smallfield B. 1993. Coriander –
Coriandrum sativum. New Zealand Institute for
Crop and Food Research Ltd.
(www.crop.cri.nz/psp/broadshe/Coriand.htm)

- although this site is geared at New Zealand
producers, it provides interesting
information about the essential oil and spice
quality

Fenugreek

Trigonella foenum-graecum L.

Family: Fabaceae (Leguminosae)

Common names: Greek hay, Trigonella

Scientific pseudonyms: *Trigonella foenum-gracilis*, *Foenum-graecum officinale* Moench

Although one of the oldest cultivated medicinal plants in the world, fenugreek is a recent novelty to Canada. It has attracted much attention as a possible forage crop, as it has proven to be an excellent legume silage with additional compounds beneficial to cattle. Fenugreek is a plant with noted hypocholesterolaemic and hypoglycaemic activity (Newall et al. 1996) and a possible supplement for the treatment of diabetes. Development of an industry that could economically extract all components of fenugreek seed would result in greatly increased demand and production (Slinkard 1996).

Description and Habitat

Fenugreek is an erect, hardy annual herb that typically grows to a height of 0.3-0.6 m. It has a smooth and hollow, little-branched stem adorned with alternate, trifoliate leaves which are borne on a short petiole with two small stipules at the base. Leaflets are oval, slightly toothed and their upper leaf surface is pilose (Chiej 1988).

Fenugreek blooms early during the summer, producing yellowish-white (sometimes violet-tinged) unstalked flowers in the leaf axils (Bunney 1992). These may occur singly or in pairs. Later, slender and slightly curved brown pods develop, each containing approximately 20 small yellow seeds delineated by a deep furrow. Each part of the plant is sharply aromatic with a pleasant, spicy smell (Bunney 1992).

The reported life zone of fenugreek is 8-27°C, although it is reportedly hardy to -15°C (Duke 1985). It matures anywhere between 115-130

days, depending on the suitability of the weather. The plant thrives on rich, well-drained and sunny soil, encumbering weak and slow growth in cool, wet weather (Simon et al. 1984). Agronomic studies indicate that fenugreek is best adapted to the Dark Brown soil zone (Slinkard 1996).

Fenugreek has the ability to form symbiotic associations with nitrogen-fixing bacteria via root nodules. As such, it can supply up to two-thirds of its nitrogen requirement from the atmosphere and thrive on otherwise inadequate soil. The dry matter yield after 19 weeks of growth has been measured at 10.4 tonnes/ha and has a nutritive value comparable to early bloom alfalfa (Mir et al 1997).

Cultivation & History

Fenugreek is native to an area extending from Iran to North India. It was introduced to central Europe at the start of the 9th century and today is widely cultivated for its edible seed in warm temperate and tropical regions ranging across the Mediterranean, Argentina, France, India, Ukraine, China, North Africa and the U.S.

Fenugreek as a forage crop is quite a recent novelty in Canada, where it has proven to be an excellent legume silage. It has great potential as an alternative crop on the prairies because it is well adapted to the climate (Blade 1999). It produces dry matter yields equivalent to two cuts of alfalfa and is comprised of 16-18% protein; compared to 18-20% for alfalfa (Small 1999). Like alfalfa, it is a high quality legume that fixes nitrogen, but while alfalfa is a perennial, fenugreek is an annual. It also holds its quality after blooming, giving producers more flexibility for harvest and may also be bloat safe.

Fenugreek was first planted in Saskatchewan on a commercial scale in 1991 with approximately 100 acres seeded in 1993 and 200 acres in 1996. Market demand as a spice crop is extremely limited, although the opportunities in the nutraceutical industry have yet to be fully explored. Trial testing around Saskatoon in 1990 showed that the variety "Amber" produced twice as much seed as an Australian variety and matured earlier, although it has often failed to mature normally in western Canada. International sales presently amount to 10,000 - 15,000 tonnes annually, with the most important market being the Middle East.

Cultivation of fenugreek has been described as complicated as the seed is ripened intermittently over a period of some weeks and seed production can be hampered by cool moist summers (Woodward *et al.* 1982). While the plant will thrive in warm conditions, cold and wet soils will favour seed decay.

Fenugreek should be seeded in early May on light, well-drained soil and on stubble, all factors designed to promote drought stress and thus earlier maturity (Slinkard 1996). In a field experiment on a loamy sandy soil, highest seed yield was obtained by sowing fenugreek at spacing of 30 cm rows (Kumawat *et al.* 1998). Similarly, trials conducted at the University of Saskatchewan found that a density of about 18 plants per meter of row in rows 15-30 cm apart resulted in reasonable yields (or 6-12 plants/ft²; 66-132 plants/m²). Denser stands result in more uniform maturity (Slinkard 1996). Seeds will germinate in two days and emerge in seven.

Studies by the University of Saskatchewan have shown that seed shattering is not a problem and plants can be harvested in a manner similar to alfalfa seed; left in the field until dry-down, usually after a severe frost, and then direct combined (AAFRD). Expected yield is 550-900 lbs/acre (SCR).

Products & Uses

Fenugreek has several uses as a food and condiment, nutraceutical agent, medicinal supplement, forage crop and as a potential steroid source. Fenugreek seed is available in powdered capsule form and in herbal teas in local health food stores and pharmacies.

• Food & Condiment

Fenugreek seeds can be cooked or sprouted and eaten raw, having a strong, spicy flavour suitable for flavouring or spicing various foods (PFAF). Seeds may also be roasted for coffee or tea (AAFRD). As a condiment, essential oil derived from the seed is used for flavouring of imitation maple syrup, vanilla compositions, as well as rum and butterscotch. The ground seed is also used in curry and dyes.

The plant itself is quite nutritious, being high in proteins, ascorbic acid, niacin and vitamin K (Simon *et al.* 1984); young seedlings can therefore be used for vegetables.

• Nutraceutical Applications

Fenugreek has shown evidence of proving beneficial in the treatment of diabetes and high cholesterol. Fenugreek seed endosperm contain high amounts of galactomannans used as thickening agents in the food industry (Slinkard 1996). Those in the diet help reduce cholesterol in both blood and plasma glucose levels.

Hypoglycaemic activity in healthy individuals has been reported for whole seed extracts, with slightly lesser activity exhibited by gum isolate, extracted seeds, and cooked seeds (Newall *et al.* 1996). Chronic ingestion of extracted seeds for 21 days by non insulin-dependent diabetics improved plasma glucose and insulin responses and reduced 24 hour urinary glucose concentrations.

Furthermore, in two insulin-dependent subjects, daily administration of 25 g of fenugreek seed reduced the fasting plasma-glucose profile, glycosuria and daily insulin requirements from 56 to 20 units. Also, a significant reduction in serum cholesterol concentration in diabetic patients was noted. It should be noted, however, that both the small size of the test group and lack of controls hamper any effective conclusions of this experiment.

Dr. T.K. Basu of the University of Alberta is currently investigating fenugreek consumption on the hypothesis that its dietary fibre and antioxidants will modulate cholesterol status in humans. If confirmed and its mechanisms clearly understood, this study will qualify fenugreek as a valuable nutraceutical and an ingredient of functional foods.

• Medicinal Agent

As a medicinal plant, fenugreek has traditionally been considered a carminative, demulcent, expectorant, laxative and stomachic (Simon *et al.* 1984). Most of these qualities can be attributed to the high composition of a hydrophilic mucilage in the seed (~28%) which has a soothing effect on the skin and mucous membranes (Hamon *et al.* 1985). Fenugreek has thereby found prolific usage in various ointment preparations for external use and treatment of skin irritation, wounds and burns. It has also been similarly used for sore throats and ulcers. Internally, this same mucilage has a soothing effect on the gastrointestinal tract and therefore it may be of benefit for minor stomach disorders (Hamon *et al.* 1985).

It has also been found that a seed component, fenugreekine, has antiviral activity versus the vaccinia virus. Aqueous fenugreek extract has antibacterial activity versus a variety of microorganisms that may be attributable to its flavonoid content (Bhatti *et al.* 1996). Fenugreekine also possessed cardiogenic, hypoglycaemic, diuretic, antiphlogistic and antihypertensive properties (Ghosal *et al.* 1974).

In veterinary medicine, the seeds are used to increase milk production (Bunney 1992). Seed also contain rutin, which contributes to the maintenance of normal blood flow and capillary permeability.

• **Steroid Source & Forage Legume**

Fenugreek has proven to be an excellent legume silage, yielding as much dry matter as two cuts of alfalfa with a protein content of 16-18%, compared to 18-20% for alfalfa (Small 1999). Fenugreek has a more sustained release of nitrogen in the rumen and greater mass digestion than alfalfa (AAFRD). Fenugreek contains compounds with oxytocin activity (hormones that induce milk letdown in humans and animals) and this property may be desirable for dairy cattle (Small 1999). Although cattle show initial reluctance to consume the strong-smelling fenugreek, they adjust to it in 7-10 days (Small 1999).

Fenugreek is also a natural source of diosgenin, a steroid sapogenin, a precursor of steroids used in the manufacture of birth control pills and other drugs (Small 1999). It is currently the starting compound for over 60% of total steroid production by the pharmaceutical industry (Simon *et al.* 1984). Currently, diosgenin is isolated from *Dioscorea* species although fenugreek remains a useful potential source and may one day replace present commercial sources (Small 1999). Fenugreek seeds contain between 0.1-0.2% diosgenin (Jorgensen 1988; as cited in Berti *et al.* 1993). The diosgenin content of fenugreek is also raising interest in its potential use as a forage plant for beef cattle. It is thought that with the presence of diosgenin, together with its high digestibility, fenugreek dietary supplementation may promote improved growth rates, muscle development and increased efficiency of feed utilization resulting in stronger, healthier cattle.

• **Cosmetic Applications**

Fenugreek seed contains a hydrophilic mucilage which has a soothing effect on the skin and mucous membranes, accounting for its external use in various ointment preparations including skin-nourishing face masks (Hamon *et al.* 1985). It also has the dubious function of firming the bust, achieved through its galactogogic action; increasing the flow of milk (Chiej 1988). It is recommended for preparations of aftershave, emollients, shampoos for dry hair and split ends (D'Amelio 1999).

• **Insecticide**

Fenugreek has been used as an antihelmintic against most common nematodes (Bhatti *et al.* 1996). Recently, fenugreek has also displayed a high degree of mortality in the stored product pests *Tribolium castaneum* and *Acanthoscelides obtectus* at 6 and 30 µg/insect respectively. Thus, fenugreek extract may be considered as a possible pest control.

Chemical Characteristics

Constituents

Seed Constituents (Newall *et al.* 1996):

- **Proteins and amino acids:** protein (23-25%) containing high quantities of lysine and tryptophan; free amino acids include 4-hydroxyisoleucine (0.09%), histidine, lysine and arginine.
- **Saponins:** 0.6-1.7% glycosides yielding steroidal saponins diosgenin (0.1-0.2%), yamogenin (major), with tigogenin, neotigogenin, gitogenin, neogitogenin, smilagenin, yuccagenin, fenugreekine (...)
- **Alkaloids:** gentianine, trigonelline (up to 0.13%), choline (0.05%)
- **Flavonoids:** flavone glycosides including orientin, vitexin, quercetin; tricin, naringenin and 7-O-beta-D-glucopyranoside (Nambo *et al.* 1998)
- **Others:** mucilaginous fibre (50%), vitamins including nicotinic acid, lipids (5-8%), minerals, coumarin

Seed Content (Duke 1985):

• Moisture	6.2%
• Protein	23.2%
• Carbohydrate	10.0%
• Fat	8.0%
• Fibre	9.8%
• Ash	4.3%
• Mucilage	26.3%

Whole grain content/100g edible portion (Duke 1985):

• Calories	369
• Moisture	7.8%
• Protein	28.2 g
• Fat	5.90 g
• Carbohydrates	54.5 g
• Fibre	8.00 g
• Ash	3.60 g
• Calcium	220 mg
• Phosphorus	358 mg
• Iron	24.2 mg
• B-carotene	55.0 ug
• Thiamine	0.32 mg
• Riboflavin	0.30 mg
• Niacin	1.50 mg
• Tryptophane	274 mg

Fenugreek flour content (Duke 1985):

• calories	375
• moisture	9.9%
• protein	25.5 g
• fat	8.4 g
• total carbohydrate	53.1 g
• fibre	7.1 g
• ash	3.1 g
• calcium	213 mg
• phosphorous	270 mg
• iron	32.4 mg
• thiamine	0.06 mg*
• riboflavin	0.05 mg*
• niacin	1.5 mg

*denoted in the text as (?)

Fenugreek raw leaf content per 100g (Duke 1985):

• Calories	35
• Moisture	87.6%
• Protein	4.6 g
• Fat	0.2 g
• Carbohydrate	6.2 g
• Fibre	1.4 g
• Ash	1.4 g
• Calcium	150 mg
• Phosphorus	48 mg

Methionine and acetylcholine content of fenugreek during the vegetative and reproductive states; dry weight basis (Gopala Rao et al. 1978):

<i>Vegetative Stage</i>	<i>Methionine (ug/g)</i>	<i>Acetylcholine (umole/g)</i>
• root	1500	82.3
• stem	4174	144.2
• leaf	8332	363.1

Reproductive Stage

• root	92	126.4
• stem	218	93.1
• leaf	119	283.5
• pod	2182	189.1
• seed	820	51.5

Fenugreek is also a source of the flavonoid rutin (also discussed in "Buckwheat") which contributes to the maintenance of normal blood flow and capillary permeability (Gopala Rao et al. 1978). It is found in most plant parts, but is in highest concentration in the leaves during the vegetative stage.

Toxicology (Newall et al. 1996)

Toxicity studies indicate fenugreek seeds to be relatively nontoxic with no reported side-effects. Alcoholic seed extract has been reported to be non-irritating and non-sensitizing to human skin, while it has also been shown to be non-phototoxic in mice and pigs. The LD₅₀ (rat, oral) for alcoholic seed extract is 5g/kg; the LD₅₀ (rabbit, dermal) is 2g/kg.

However, the presence of several pharmacologically active constituents would suggest that excessive ingestion is inadvisable. Coumarins and estrogen can be toxic in excessive doses. Seeds are reported to contain trypsin inhibitors and chymotrypsin inhibitors (Duke 1985).

Additionally, oxytoxic and in-vitro uterine stimulant activity has been documented for the seed extract, therefore usage in pregnant women should be avoided. The LD₅₀ (rat, oral) for various seed components :

- trigonelline = 5g
- nicotinic acid = 8.8g
- nicotinamide - 7.4g
- coumarin = 0.72g

Fenugreek is listed as Generally Regarded As Safe (GRAS) by the FDA in the US and as a

natural source of food flavouring by the Council of Europe (Newall *et al.* 1996). This allows the use of fenugreek to foodstuffs in small quantities, with a possible limitation of an active principle (as yet unspecified) in the final product, while in the US, extracts are permitted in foods at concentrations usually below 0.05%.

Extracts

Water extraction of ground fenugreek seed produced a delicious and sweet-smelling, opaque and milky yellow extract with an extractive yield of 11.9%. It was difficult to filter as it was slightly viscous. Solids are a golden orange crystalline with a gorgeous smell while residual extracted material is a dark and very clumpy, extremely hard material.

Ethanol extraction yielded a sunshine yellow extract with an extractive yield of 10.2%. Solids are an orange, slightly oily and sticky solid while the residual extracted seed material remained a light powdery substance.

Patents

There are many patents for fenugreek; mostly for herbal and medicinal products or food condiments. As with other medicinal herbs, many patents also include fenugreek as one of several utilizable herbs and are not specific for fenugreek alone. A total of 14 patents were found in the CIPO database when searched for fenugreek, 6 in the US PTO.

❖ 5900239 (99/05/04) Mai *et al.* GERMANY
Hair growth stimulating composition containing trigonelline or trigonellic acid and ginseng.

❖ 0587087 (99/02/16) Neelakantan K.
INDIA
Herbal dry shampoo composition.

❖ 00888717/ EP A1 (99/01/07) Jaeger *et al.*
FRANCE
Aroma extract; prepared by enzymatically hydrolyzing seeds, inactivating the enzyme and separating the liquid phase with the aroma compounds.

❖ CA2236739 (99/01/02) Blank *et al.*
SWITZERLAND
Flavour extract.

❖ CA2206157 (98/11/26) Chang P. CANADA
Method of extraction of commercially valuable fractions of fenugreek.

❖ CA2280093 (98/08/06) Kosbab *et al.* US
Compositions and methods for prevention and treatment of vascular degenerative disease.

❖ 00587476/EP B1 (98/03/18) Sauvaine *et al.* FRANCE
Compositions containing mono or polyhydroxylated amino acids for treatment of non-insulin dependent diabetes mellitus.

❖ 10029924 JP (98/02/03) Suzuki *et al.*
JAPAN
Antiaging agent.

❖ 05707631 (98/01/13) Lieberman C.J.
Therapeutic herbal composition.

❖ 00775451/EP A1 (97/05/28) Gopalan *et al.*
Dietary fibre containing product and process for producing same.

❖ 09713492 WO (97/04/17) Mai J.
GERMANY
Strengthening agent; for care of skin and horny structures in particular nails, hooves and claws.

❖ CA2227218 (97/02/06) Howse E.A. UK
Insect attractant.

❖ CA2009329 (97/01/14) Ammedick-Nawnann *et al.* GERMANY
Condiment; use of fenugreek for refining various sauces.

❖ 0831779 JP (96/11/19) Yamashita S.
JAPAN
External preparation for atopic dermatitis.

❖ CA2213219 (96/08/22) Steckley *et al.*
CANADA
Particular feed supplement.

❖ CA2211802 (96/08/15) van den Berghe *et al.* NETHERLANDS
Pharmaceutical composition for the treatment of Herpes.

❖ 07017845 JP (95/01/20) Honda S. JAPAN
Skin external preparation.

❖ CA2145205 (94/04/14) Pedersen *et al.*
DENMARK
Surface treatment composition.

❖ CA2202592 (98/10/14) & 05658571 (97/08/19) Gopalan *et al.* INDIA

A process for the debitterization of seed of fenugreek (*Trigonella foenumgraecum*)

❖ CA2022509 (92/02/02) Tsaparis T.L.
CANADA

Medicinal composition; promoting hair growth and treating skin disorders.

❖ 04258035 (81/03/24) Spies J.A.
Method and compound for treatment of arthritic conditions in dogs.

Cost & Availability

Plant part: seed only, blooming aerals (baled)

Sask. Availability: Fenugreek seed is grown by at least ten Saskatchewan specialty crop producers and is handled by two or more seed crop dealers. Fenugreek grown as a culinary herb (mette) is a different cultivar than that grown to obtain fenugreek seed. Fenugreek herb is grown near Vancouver and north of Toronto to serve the demand of ethnic kitchens.

Sask. Seed Prices:

Conventional

Grower Direct, bin-run: \$0.40-\$0.50/kg
Dealer's Price, clean and bagged: \$0.53-\$0.67/kg

Certified Organic

Grower Direct, bin-run: \$0.90-\$1.25/kg
Dealer's Price, clean and bagged: \$2.20-\$2.65/kg

Blooming Aerals:

Conventional

Grower Direct, 90% pure, baled: \$300-\$500/tonne

Certified Organic

Grower Direct, 90% pure, baled: \$600-\$1000/tonne

Potential Suppliers:

- ♦ Schweitzer Enterprises, Eston Sask.
(306) 962-4751
- ♦ Dwayne & Bonnie McBride, Belle Plaine
Sask. (306) 345-2080

Certified organic:

- ♦ Emerald Seed Productions Ltd. Regina
Sask. (306) 924-2033

Recommended Resources

M Fairbairn C. 1995. The grower's guide to herbs and spices. University Extension Press. University of Saskatchewan, Saskatoon.

- provides information on the marketing, agronomy, harvesting and production of fenugreek in Saskatchewan

Flax

Linum usitatissimum L.

Family: Linaceae

Common names: Linseed, Flaxseed

Scientific pseudonyms: *Linum humile* P.Mill,
Linum usitatissimum L. var. *humile* (P.Mill) Pers.

"What department is to be found in active life in which flax is not employed?" This praise for flax was proclaimed nearly two thousand years ago by the first-century Roman natural historian Pliny. Today, flax is still a facet in a variety of products and gaining even more attention as efforts amplify to promote environmentally-friendly products. Further, flaxseed is gaining renown for its benefits as a feed supplement and much attention is being paid to its nutraceutical properties.

Description & Habitat

Flax is an introduced erect, glabrous annual herb. It has a tall, slender and leafy stem, 75-120 cm high, which is usually branched at the top (Bunney 1992). Leaves are simple and alternate, sessile, linear-lanceolate in shape and are borne on stems and branches. They are 2-3.5 cm long and marked by three prominent veins. Flax has a short tap root with fibrous branches which may extend 90-120 cm in light soils, with side branches stretching approximately 30 cm.

The main stem and branches give rise to a multi-branched, irregular arrangement of flowers. The blue or white flowers are arranged in a loose terminal panicle. Flower opening begins shortly after sunrise on clear, warm days and petals are shed in the early afternoon (CFIA 1994). The fruit is a capsule, composed of 5 carpels and may contain up to 10 seeds. Ripening of the capsule begins 20-25 days after flowering. The seed is oval, lenticular, 4-6 mm long with a smooth shiny surface, brown to light-brown in colour. The seed is covered with a coating (mucilage) that gives it a high shine and causes the seed to become sticky when wet.

Cultivated flax is a highly self-pollinated species therefore oil content and quality remain highly heritable traits. Other than in cultivation, flax is reportedly found as an escape in waste places and along roadsides (CFIA 1994). As well, in most countries outside of North America, flax is more commonly known as linseed.

Environmental factors such as temperature (particularly after flowering), soil conditions, cultural practices and the presence of disease are all known to affect oil content and quality (Oomah *et al.* 1998). Cool growing conditions usually result in low protein and high oil content (DeClercq *et al.* 1995). As well, higher seed protein levels can be achieved by crop management such as increased application of nitrogen and phosphorus fertilizers (Singh *et al.* 1978).

Cultivation & History

Common flax is one of the oldest continuously cultivated plants in history (Haggerty 1999) and one of the first domesticated by humans (Oplinger *et al.* 1989). It is thought to have originated in the Mediterranean region of Europe. The use of flax seed and fibre can be traced back to the Stone Age and has since been utilized to enwrap Egyptian mummies and fabricate the sails of the Roman naval fleet. It is possible to date the cultivation of flax to early Greek civilization from flaxseed excavated and dated to this time period (Haggerty 1999).

Currently, Canada produces about 40% of the world's flaxseed and is the world's largest exporter of flaxseed, representing about 75% of world trade. Canada is a major producing country along with Argentina, India, the USA and Russia; most Canadian flax is exported as flaxseed. Canada is the only significant exporter of flaxseed to the European Union, the United States and Japan (Oomah *et al.* 1998). Saskatchewan produced 724,000 tonnes of flaxseed in 1999 with a yield of 525 kg/acre, accounting for 67% of the total 1999 Canadian production (SAF).

Two types of *Linum usitatissimum* are cultivated: the linseed type, grown for oil extracted from the seed is a relatively short plant which produces many secondary branches compared to the flax type, grown for the fibre extracted from the stem, which is taller and less branched (Gill 1987). From the handling, registration and marketing standpoint, there are two types of commercially produced oilseed flax: traditional

flax or linseed and the newly developed solin which contains less than 5% linolenic acid (Oomah *et al.* 1998). The only registered varieties of solin in Canada are Linola 947 and Linola 989 (Oomah *et al.* 1998). In Canada, the vast majority of flaxseed produced is of the short fibre oilseed variety which is grown primarily in the three prairie provinces of western Canada, specifically in southern Manitoba, Saskatchewan and Alberta (AAFC 1999).

Due to its limited root system, flax does not grow well on sandy, moisture-limited soils but prefers heavy loam soils that are moisture-retentive. Research in Saskatchewan has shown that flax sometimes does poorly after canola or mustard due to toxic compounds in mature canola and mustard plants (FCC 1996). For complete agronomic instruction, please refer to "Growing Flax: Production, Management & Diagnostic Guide" published by the Flax Council of Canada and available at any Saskatchewan Agriculture & Food Rural Extension office.

Products & Uses

From prehistoric times to the present, flax has been a source for food, fibre and oil, and has been used in herbal preparations (Haggerty 1999). Besides being rich in alpha-linolenic acid oil and good quality protein, flaxseed has potential as a natural source of phytochemicals such as flavonoids, lignans and phenolic acids (Oomah *et al.* 1998).

• Fibre (Duke 1983)

Linen is the most important product made from the fibre of the flax plant. It is soft, lustrous and flexible, although not as flexible or elastic as cotton or wool. Fibre yields run 20-1200 kg/ha. Flax fibres are in the cambium layers of the plant and are the bast or phloem fibres: each stem contains about 30 fiber bundles comprised of 10-40 individual fibres. Retted flax contains about 64% cellulose, 17% hemicellulose and 2% lignin.

High quality fibres are spun into a variety of fine fabrics and clothes for use in the fabrication of clothing, bedding and more. Flax clothing is recently enjoying a resurgence in popularity on the fashion industry of Europe. Lower quality fibres manufacture towelling, matting, rugs, twines, canvas, bags and quality papers, as for printing currency notes. Further utilization of flax straw in the production of construction

panels, furniture and more is currently being investigated by Dr. Keith Domie of the University of Alberta.

Cargill Limited, the Government of Saskatchewan and Sask-Can Fibre Inc. operate North America's first large-scale commercial agricultural fibre processing facility in Canora with an annual production capacity of 60,000 tonnes. Among its products is Durafibre, a strong fibre derived from flax straw which has potential to replace fibre glass in the manufacture of car-door panels, a practice already utilized by European car manufacturers such as BMW (Flax Focus 1997).

• Industrial Uses

Seeds are the source of linseed oil (38-40%), a drying oil, one of the oldest to have been used commercially. Paint and varnish industries consume about four-fifths of the linseed oil produced. It is also used in enamels, linoleum, oilcloth, patent leather as well as waterproofing for raincoats, slickers and tarpaulins (Duke 1983).

Although the market for linseed oil agents in paints and inks has been eclipsed by the production of synthetic resins and latex, one bright spot in the market has been the use of linseed oil as an antispalling treatment for concrete where freezing and thawing effects have created problems on streets and sidewalks (Oplinger *et al.* 1989). A testing program completed at the University of Hong Kong in 1996 proved conclusively that flax oil-based preservatives extend and enhance the life of concrete in parking, structures, bridges, concrete buildings and prevent the breakdown of reinforcing steel (FCC).

Flax oil is also being touted as an environmentally-friendly product. It is being utilized in the production of completely biodegradable liquid detergent named *Mousse de Lin* by a Belgian company (FCC). Further, flaxseed oil-based linoleum is completely biodegradable when disposed, while paint and fibreboard products replace some solvent and petroleum-based chemicals in the products' formulations, thereby combating air pollution and reducing volatile organic compounds.

• Food & Nutraceutical Uses

Flaxseed, a rich source of omega-3 fatty acids, recently received top billing as a health-promoting food by prominent nutrition researchers with beneficial effects in the

prevention of sudden death from heart arrhythmia, coronary heart disease and cancer (FCC).

Flaxseed's nutraceutical effects are believed to be caused by several factors (Haggerty 1999):

- Its oil contains high levels of the essential fatty acid alpha-linolenic.
- Flaxseed fibre contains high levels of a lignan called secoisolariciresinol diglucoside: lignans have anti-tumour, antimitotic, antiviral and enzyme-inhibiting biological activities.
- The gums and mucilage present may contribute beneficial effects.

Although flaxseed oil has been consumed for centuries in India, China and Europe, it is traditionally considered a non-edible oil in many western countries due to its rapid oxidation and polymerization, and it does not have GRAS status (Generally Recognized As Safe) (Oomah *et al.* 1998). Thus began the development of the solin flax type, which contains low (<3%) alpha-linolenic acid for improved stability and competitiveness as a salad or cooking oil.

Flaxseed oil is rich in omega-3 fatty acids known to influence blood platelet aggregation, lower blood cholesterol concentration and prevent coronary heart disease (Kolodziejczyk *et al.* 1995). Many flaxseed oil supplements are now commercially available, such as the one illustrated below.

Although fairly abundant in flaxseed, protein has received relatively little attention. However, opportunities exist for processing flaxseed in the production of protein concentrate and protein isolate (large-scale production of flaxseed protein is nonexistent at the present time, although several methods of protein extractions have been attempted) (Oomah *et al.* 1998).

Flaxseed as a source of vegetable protein is commercially available in the form of whole seed, full-fat flour (i.e. milled flaxseed) and meal. Defatted flax flour is an excellent natural additive for improving the texture of bakery products (Kolodziejczyk *et al.* 1995). The protein score, based on most limiting amino acids, relative to FAO (Food and Agriculture Organization) nutritional requirements, is 82 for flaxseed meal and 67 for soybean meal (Sosulski *et al.* 1973). Defatted flaxseed has been shown effective in lowering blood cholesterol levels by

dietary supplementation of muffins containing 20g flaxseed fibre (Jenkins *et al.* 1999).

Flaxseed has been included as whole grain in breakfast cereals, muffins and cookies (Oomah *et al.* 1998). Flaxseed may also be roasted as coffee substitute or brewed as a herbal tea (PFAF). Flaxseed finds major application in baked items where the blending with cereals increases both the quantity and quality of the protein in the cereal products (Oomah *et al.* 1998).

• **Medicinal Uses**

Flaxseed has an extended history of medical and therapeutic use. The first century Greek physician Dioscorides lauded flaxseed's power for "mollifying all inflammation inwardly and outwardly". External use of linseed oil has been recommended to treat sprains, burns and wounds, usually in the form of a poultice (Hamon *et al.* 1985).

Flaxseed oil contains exceptionally high amounts of lignan precursors, which are anti-tumourigenic agents (Kolodziejczyk *et al.* 1995). Defatted powdered seed contained secoisolariciresinol diglucoside (0.7 ug/g) which is thought to be the precursor for both enterodiol and enterolactone, which are thought to be involved in cancer prevention (Harris *et al.* 1993). Treatment with secoisolariciresinol diglucoside (SDG) has also reduced serum total cholesterol by 33% and reduced atherosclerotic plaques by 73% in rabbits on a high cholesterol diet (Muir *et al.* 1999). SDG also has antioxidant activity (Prasad 1997).

Several bioactive functions, such as antioxidant, antimicrobial and anticancer, have been attributed to phenolic acids (Oomah *et al.* 1998). Flaxseed is also currently being investigated as a possible treatment for lupus, malaria and rheumatoid arthritis (Haggerty 1999).

• **Animal and Poultry Feed (FCC)**

Linseed oil meal (the remaining flax cake following oil extraction with a remaining 3-6% oil content) is an excellent protein source for livestock containing about 35% crude protein (Oplinger *et al.* 1989). Cake is prepared for feeding by grinding to linseed meal or by making pellets suitable for feeding in outdoor feed lots or on the range (Duke 1983). Flax straw makes a very poor quality forage because of its high cellulose and lignin content (Oplinger *et al.* 1989).

Much research has been conducted on the incorporation of flaxseed into animal and poultry feed. Flaxseed has very successfully been incorporated into the rations of laying hens which has resulted in the production of essential fatty-acid rich eggs. Using flaxseed as 10% or 20% of a poultry ration can increase alpha-linolenic acid content of egg yolk fat from 0.4% in the ordinary egg to 4.6% and 8.9% respectively. These nutritionally-enhanced eggs now supply 4% of the Canadian egg market.

The addition of flaxseed to poultry diet has been found to show increased levels of gamma-linolenic acid and linoleic acid in the lipid content of both white and dark meat. In the pet food industry, it is thought that the addition of flaxseed may improve pet health in a manner similar to human health.

Chemical Characteristics

Constituents

Composition of flaxseed (Duke 1983):

• calories	498
• moisture	6.3-6.6%
• protein	18-20.3%
• fat	34-37.1%
• carbohydrate	33.6-37.2%
• fibre	4.8-8.8%
• ash	2.4-4.5%

Seeds also contain 15% mucilage along with wax, resin, sugar, phosphates, acetic acid and a small quantity of the cyanogenic-glucoside, linamarin. Other cyanogenic glycosides include linarmarine-B-glycoside, linustatin, neolinustatin and lotoustralin (Hamon *et al.* 1985).

Oil composition of flaxseed (Oplinger *et al.* 1989):

<i>Fatty acid</i>	<i>% total fatty acids</i>
• linolenic	49.3%
• linoleic	14.7%
• oleic	24.1%
• stearic	4.3%
• palmitic	6.1%

Mineral composition of flaxseed (Oplinger *et al.* 1989):

<i>Mineral</i>	<i>Composition</i>
• potassium	0.89%
• phosphorous	0.60%
• magnesium	0.33%
• calcium	0.21%
• sodium	0.04%

• zinc	56.9 ppm
• iron	46.2 ppm
• manganese	32.0 ppm
• boron	11.5 ppm
• copper	9.5 ppm
• strontium	1.4 ppm
• molybdenum	0.7 ppm

Essential amino acid composition (g/16g N):

• arginine	8.4 g
• histidine	1.5 g
• lysine	2.5 g
• tryptophan	1.5 g
• phenylalanine	5.6 g
• methionine	2.3 g
• threonine	5.1 g
• leucine	7.0 g
• isoleucine	4.0 g
• valine	7.0 g

Composition of flaxseed protein products: **(Oomah *et al.* 1998)**

<i>Protein product</i>	<i>P</i>	<i>L</i>	<i>C</i>	<i>A</i>
• Isolated flaxseed protein	86.6	trace	NR	NR
• Flaxseed protein concentrate	65.5	0.8	NR	NR
• Commercial flaxseed meal	39.2	13.6	NR	5.58
• Defatted flaxseed meal	42.2	0.6	17.8	7.42
• Whole flaxseed	23.5	43.8	9.9	4.81

NR= not reported

P= protein

L= lipid

C= carbohydrate

A= ash

Major phenolic acids present in dehulled, defatted flaxseed (Oomah *et al.* 1998):

• Ferulic acid	46%
• Sinapic acid	36%
• p-coumaric acid	7.5%
• caffeic acid	6.5%

Flaxseed contains 8-10 g/kg of total phenolic acids.

Composition (% moisture-free basis) of flaxseed at various processing stages (Oomah *et al.* 1998):

	<i>Seed</i>	<i>Flake</i>	<i>Cake</i>	<i>Meal</i>
Crude protein	20.35	21.34	30.42	34.47
Fat	43.79	39.37	17.26	5.72
Ash	4.03	3.98	5.86	7.25
Carbohydrates	9.86	9.92	14.97	15.18
Total phenolics	1.42	1.59	1.34	0.99

Extracts

Water extraction of ground flaxseed produced an oily, viscous extract with an opaque light yellow colour and an extractive yield of 37.8%. (Note: due to the difficulties in filtering the extract, the solids content may be higher than actual). Filtration proved quite difficult due its thick viscosity; only a small amount could be successfully vacuum filtered while the remainder required cheese cloth and centrifuging. The dried residue seed material is an extremely hard, clumpy dark solid.

Ethanol extraction produced a clear, bright yellow extract with an extractive yield of 41.6%. Dried solid is a yellow-orange oil with some crystalline precipitate. Residually extracted seed material much resembles the starting material: a pale yellow powder with some dark bits of seed shell.

Toxicology

The seed of some strains contain a small amount of the cyanogenic glycoside, linamarin (Duke 1983). The toxicity of seeds is generally thought to be low (PFAF). However, 0.22 kg (half pound) of flowers will cause death of cattle (Duke 1983). Symptoms of toxicity include stimulation of respiration, changing to dyspnea, excitement, paralysis, convulsions, coma and death (Hamon *et al.* 1985). Green flax straw is also high in prussic acid; the danger of prussic acid poisoning in grazing cattle is greater immediately following a freeze (Oplinger *et al.* 1989).

Patents

A patent search of *Linum usitatissimum* yielded few results in both the US PTO and CIPO, however over 300 patents on CIPO matched the query for flax. These patents range from nutraceutical and pharmaceutical products to fibre products, resin compositions and oil uses. Patents of various uses are listed below, but for a complete listing, please refer to the CIPO website.

- ❖ CA2255281 (99/07/04) Pedersen P.
DENMARK

Production of a patterned knitwear product for use as a garment, in particular of the sweater type.

- ❖ 5846944 (98/12/08) Prasad K.
SASKATOON

Compound secoisolariciresinol diglucoside (SGD) obtained from flaxseed is used for reducing/preventing development of hypercholesterolemic atherosclerosis and for reducing total cholesterol in humans, animals and for the treatment of diabetes.

- ❖ CA2069435 (98/06/09) Bastiansen *et al.*
DENMARK

Plate of flax fibre felt.

- ❖ 09208461 JP (97/08/12) Kuriyama *et al.*
JAPAN

Active oxygen scavenger and colour fading inhibitor.

- ❖ CA2215667 (96/09/19) Dear *et al.* UK
Stabilization of bio-organic sludges; designed to treat sewage, meat/dairy works from putrefication of microbial decomposition by addition flax as a source of bioorganic material.

- ❖ CA2179820 (96/06/06) Gardill R.F.
GERMANY

A molded panel having a decorative facing.

- ❖ 00478837/EP A1 (95/01/25) Nitsch E.
GERMANY

Lactulose preparation and its manufacturing process.

- ❖ CA2075341 (94/01/07) Chen C-T.
TAIWAN

Textured venetian blind and method of making the same.

- ❖ CA2080725 (93/11/26) Kasbo *et al.* US
Animal litter composition and package; comprised of decorticated flax straw.

- ❖ 5260282 (93/11/09) Attstrom *et al.*
SWEDEN

Saliva substitute; comprised of water-soluble linseed polysaccharides for use as a carrier for pharmaceuticals adapted for oral applications.

- ❖ CA1310875 (92/12/01) Fields *et al.* US
Sidestream reducing cigarette paper.

- ❖ CA1275523 (90/10/23) Yasakawa *et al.*
JAPAN

Polypropylene resin composition.

- ❖ CA1264639 (90/01/23) Isler B.J. US
Artificial fingernails and method of application; formed from layers of organic fibre.

❖ 63237745 JP (88/10/04) Okuyama H.
JAPAN
Production of animal food with enriched content
of linolenic acid based fatty acid.

❖ 62210991 JP (87/09/17) Yamada et al.
JAPAN
Production of crude drug.

❖ CA1223495 (87/06/30) & CA1192808
(85/09/03) Mathews et al. US
Reduced ignition proclivity smoking article
wrapper and smoking article.

❖ CA1302254 (92/06/02) & CA1336553
(85/08/08) Stitt P.A. US
Stable nutritive and therapeutic flax seed
compositions, methods of preparing the same,
and therapeutic methods employing the same.

❖ CA1107121 (81/08/18) Schanze R.
GERMANY
Feedstuff or feedstuff additive and process for
its production; a novel animal foodstuff.

Cost & Availability

Plant part: seed only

Sask. Availability: Widely grown oilseed crop.
Available both conventionally grown and
certified organic.

Sask. Price:

Conventional

Grower Direct, bin-run: \$0.25-\$0.32/kg
Dealer's Price, clean and bagged: \$0.35-
\$0.49/kg

Certified Organic

Grower Direct, bin-run: \$0.65-\$0.79/kg
Dealer's Price, clean and bagged: \$0.79-
\$0.90/kg

Potential Suppliers:

- ♦ *Conventional* - Schweitzer Enterprises,
Eston Sask. (306) 962-4751
- ♦ *Certified Organic* - Buyers may wish to
contact the Organic Products Info Service
operated by the Saskatchewan Research
Council (306) 933-5400

Recommended Resources:

M Flax Council of Canada
(<http://www.flaxcouncil.ca>)

- A very comprehensive and well-organized
site with information on research, nutrition,
industrial products, suppliers, and much
more.

M Duke J.A. 1983. Handbook of Energy
Crops. Unpublished. NewCROP: New Crop
Resource Online Program.
(<http://www.hort.purdue.edu/newcrop/>)

M Haggerty, William J. 1999. Flax: Ancient
Herb and Modern Medicine. *HerbalGram* 45:
51-57.

M Oomah B.D. & Mazza G. 1998. Flaxseed
products for disease prevention. In: Mazza G.
(ed.) Functional foods: biochemical and
processing aspects. Technomic Publishing,
Lancaster VA.

- For anyone interested in precise
nutraceutical applications, this is the paper
to read. Contains very detailed information
about biologically active components,
processing methods and products, health
benefits and chemistry.

Gumweed

Grindelia squarrosa (Pursh) Dunal

Family: Asteraceae (Compositae)

Common names: Rosinweed, Tarweed, Curly-top gumweed, Curlycup gumweed, Broad-leaved gumplant, Matchweed, Green rabbitbrush

Scientific pseudonyms: *Grindelia perennis* A. Nels. Four varieties are also listed by the USDA.

Gumweed is a species with tremendous potential for industrial applications. A common weed, its growth characteristics highly favour domestication and it appears to be well suited to intensive cultivation. Historically, gumweed has been a traditional medicinal herb with many highly appreciable aromatic qualities. However, with the virtual exhaustion of high-quality wood rosin from pine stumps, gumweed has recently been the subject of much investigation as a possible resin source. Its production of sizable amounts of chemically distinct diterpene resins may provide the opportunity for formulation of a new generation of improved rosin derivatives which have a wide and diverse industrial application.

Description & Habitat

Gumweed is a smooth-stemmed, branching perennial forb most readily characterized by its strongly aromatic leaves and flowers; a sweet, spicy and pungent smell. In its first year of growth it forms a small rosette which, the following summer, will produce highly branched erect stems with many flower heads (Walsh 1993). Gumweed is a very fast growing herb, producing much biomass early in its growth phase. In a North Dakota study, gumweed began growing in May and by month's end, had attained 50% of its yearly growth (Goetz 1963). Gumweed attains a height of 20 to 60 cm and its foliage is comprised of serrated, linear-oblong leaves which are stiff and brittle.

A large number of bright yellow flowers, appearing between July and September, are comprised of an involucre; many series of very sticky, gummy bracts (Duke 1985). Individual florets remain open for one day and in hand-pollination studies, produced yields ranging from 21-71 achenes per capitulum. The average blooming period is 41 days; the median date when flowering was 95% complete was September 4 (Callow *et al.* 1992). Gumweed fruit is an achene which matures approximately 22 days following pollination (McLaughlin 1995).

Resin is produced in sessile, multicellular glands found on the involucre bracts, leaves and stems of the plant; the density of resin glands is highest on the involucre bracts of the flower head (~20%), lowest on the stems (~2%) and intermediate on the leaves (~14%) [McLaughlin 1995]. Resin production protects the plant from heat and dessication in arid environments and is usually highest in the delicate reproductive structures (capitulum). Gumweed has a taproot which can extend 2 m into the soil, with extensive shallow root development comprised of short, vertical rhizomes (Walsh 1993).

Gumweed is widely distributed throughout Saskatchewan and North America, ranging south to Texas and Mexico (Sievers 1930). It is one of approximately 40-60 species of *Grindelia* native to the temperate regions of North and South America (McLaughlin 1995). Species of *Grindelia* are often poorly differentiated and the complete taxonomy of the genus is still poorly understood (McLaughlin 1995).

Grindelia squarrosa is common on dry prairie (being present throughout the entire unwooded part of the prairie provinces), roadsides, waste areas and especially on somewhat saline flats and slough margins (Duke 1983). Gumweed possesses little forage value and is relatively unpalatable to all classes of livestock therefore its local abundance is often an indication of depletion due to severe and prolonged overgrazing (Duke 1983). Gumweed is also listed as a noxious weed in several states in the US (Walsh 1993).

Cultivation & History

Gumweed is a traditional Amerindian medicinal species that was used to treat asthma and bronchitis (Duke 1985). There are several

Grindelia species used medicinally including the less common *Grindelia robusta* and *Grindelia lanceolata*, whose Saskatchewan ranges are more respectively, southwestern and eastern. But for all practical historical and current medicinal purposes, *Grindelia* species are generally used interchangeably, depending on which species is available. The plant is harvested when in full bloom and used fresh as a poultice or dried for later use (PFAF).

Gumweed shows a high ability to survive and grow under adverse conditions. Both direct seeding and seedling transplant show excellent results (Nuzzo 1978). When planted, germination time for seeds is approximately 3 days following seed stratification. In its first year of growth, it forms a rosette and the next summer, the plant grows erect stems which branch considerably and produce many flower heads (Walsh 1993). The optimum planting density for *Grindelia* species is 33,000 plants/ha (McLaughlin *et al.* 1987). It can also be propagated by cuttings (PFAF).

Grindelia camporum has been most extensively studied for cultivation and it has been found that resin content decreases from 12-15% to 9-10% under cultivation (McLaughlin *et al.* 1987). Economic analysis show that a resin content of 15% is necessary for *Grindelia* to develop into a commercial crop (Hoffmann *et al.* 1986). In general, the crude resin content of native stands is higher than in cultivated efforts (Ravetta *et al.* 1996). Such reduced resin production could be due to improved soil-water and nutrient availability under cultivation as well as air temperature during growth and at harvest date (Ravetta *et al.* 1996). Resin content of *Grindelia squarrosa* has been measured at 16% for flowering aerals and 2% for leaves (Didry *et al.* 1982).

Plants are cut and dried in the field for 2-5 days and then hammermilled with a 4 mm screen and stored pending extraction (McLaughlin 1995). Yields obtained in the laboratory from individually harvested plants appear to be 2-3% higher than yields observed from samples of bulked, field-dried, hammermilled plants and may be due to loss of leaf material during collection and handling or hammermilling.

Grindelia squarrosa, as well as *Grindelia camporum*, appear to be well suited to intensive cultivation on arid or semi-arid lands (Aronson 1984). Reasonably compact and fast-growing, they should prove amenable to either

annual or perennial cropping systems employing full mechanization (Aronson 1984). Seeds germinate readily and little or no pest or disease damage was observed in test trials.

Products & Uses

• Rosin Substitute

One of the most exciting uses to be contemplated for this species is as a rosin substitute. *Grindelia* produces sizable amounts of diterpene resins, composed of grindelic acid and several derivatives, which are chemically similar to the resin acids that constitute rosin, a large class of chemicals including turpentine (Duke 1983). Rosins have a wide and diverse industrial application and the supply of high-quality wood rosin, extracted from aged pine stumps, is virtually exhausted.

A study of the University of Arizona's Bioresources Research Facility examined the *Grindelia* species *camporum* as a potential source of rosin. It was found that:

- current germplasm of *Grindelia camporum* produces ~10% crude resin which equates an annual yield of 1,135kg/ha
- growth characteristics favour domestication: upright, herbaceous grown, annual cycle and the ability to regenerate growth from the root crown to produce two crops/growing season
- good tolerance to salinity, disease and drought
- chemically distinct forms of diterpene resins may provide the opportunity for formulation of a new generation of improved rosin derivatives

Various species of *Grindelia* have been patented for use of their resins in adhesives, rubber, coatings, textiles and polymers. *Grindelia* resins could provide a potential alternative source of diterpene resin acids for use in inks, sizings, adhesives, tackifiers and other naval stores products (McLaughlin 1995).

• Medicinal Uses

Gumweed has long been used by natives as a remedy used for a variety of ailments including cancer of the spleen and stomach, burns, colds, pneumonia, gonorrhea, smallpox and tuberculosis, to name a few. The dried leaves and flowering tops are anti-asthmatic, anti-

inflammatory, anti-spasmodic, expectorant and sedative (PFAF).

Gumweed has also shown significant antibacterial activity versus various microorganisms that is attributable to its resin and various polyphenolic constituents (Didry *et al.* 1982).

Grindelia has contemporary usage as listed in the British Herbal Pharmacopoeia: an antispasmodic, expectorant and cardiac depressant. Its specific indication is for bronchial asthma associated with tachycardia. The plant merits investigation as a treatment for asthma (Foster *et al.* 1990). There are many herbal remedies which utilize gumweed as an ingredient for asthma, sinus and congestive disorders. It is usually in combination with other herbs.

Gumweed can be utilized as a slightly bitter but pleasing tea (PFAF), a liquid extract, lotion or tincture. Its sap can also be used as a chewing gum substitute (Facciola 1990) although tannins, volatile oils, resins, bitter alkaloids and glucosides give gumweed an unpleasant taste (Bare 1979).

Chemical Characteristics

Constituents

In *Grindelia squarrosa*, 10 polyphenolic compounds have been identified (Pinkas *et al.* 1978):

- p-hydroxybenzoic acid
- vanillic acid
- p-coumaric acid
- quercetin
- luteolin
- 3-methylquercetin,
- 3-methyl-kaempferol
- 3-3'-dimethylquercetin
- 3,7-dimethylkaempferol
- ferulic acid

Grindelia squarrosa herb constituents (Duke 1985):

- 20% resin
 - 7-alpha-8-alpha oxodihydrogrindelic acid
 - grindelic acid
 - oxygrindelic acid
 - 6-oxygrindelic acid

- 0.3% essential oils; largely borneol
- 0.2% choline
- tannins (8% hamamelitannin)
- saponins
- alkaloid grindeline
- p-oxybenzoic acid
- matricarianol and matricarianol acetate

The total extractable phenolic fraction has been measured at 10% for flowering tops and 3.2% for leaves (Didry *et al.* 1982). Alpha-pinene (25.53%) is the major compound (Kaltenback *et al.* 1993).

Sapogenins isolated in *Grindelia squarrosa* and other *Grindelia* members include oleanolic acid, bayogenin and grindeliasapogenin D (Kreutzer *et al.* 1990).

Grindelic acid is the primary component of the resin in most species of *Grindelia* of North and South America (McLaughlin 1995). Several of its derivatives that occur in lower yields include 17-acetoxygrindelic acid, 13-isogrindelic acid, 7,8-epoxygrindelia acid and strictanoic acid.

Dry seeds contain (Duke 1985):

- protein 13.8%
- fat 19.6%
- ash 3.4%

Toxicology

Contains the carcinogen safrole (though in much smaller quantities than sassafras), eugenol and acetaldehyde (Duke 1985). Large doses are reported to cause renal irritation (BHP 1991).

Extracts

Water extraction of ground gumweed aerals produced a clear light brown, dark yellow extract with a strong, sweet and highly-astringent piney smell and an extractive yield of 20.4%.

Ethanol extraction yields a clear yellow-green extract with an extractive yield of 27.9%. Solids are an enormously gummy, black and tar-like gum. To obtain the pure rosin fraction, extraction must proceed with hexane as the extractive solvent. Extraction will yield a lemony-yellow, strongly scented gum that is extremely sticky and a non-solid at room temperature.

Patents

A search of CITO for *Grindelia squarrosa*, *Grindelia* and gumweed yielded no patents. A single patent was located for *Grindelia* in the US PTO:

♦ 48062856 (89/02/21) Hoffman et al.
Hydrogenated *Grindelia* acids and their methyl, glycerol and pentaerythritol esters; tackifiers from *G. camporum*.

Cost & Availability

Plant part: Flowering aerial

Sask. Availability: Plant grows in dense large patches in extreme southeast of province and in more westerly regions of southern Saskatchewan. Associated with over-grazed pasture, dry gravelly sites. Often grows in conjunction with green foxtail. Could easily be cut and bundled by wildcrafters.

Sask. Price:

Harvester Direct, bundle or baled: \$4.50/kg
Dealer's Price, milled: \$11-\$13/kg

Note: Harvest season extends from mid-July through September.

Potential Suppliers:

♦ Parkland Botanicals, Togo Sask.
(306) 597-2146

Recommended Resources

N McLaughlin S.P. 1995. *Grindelia*.
Centre for New Crops and Plant Products.
Purdue University.
(<http://www.hort.purdue.edu/newcrop/>)
• includes information on the uses, resin chemistry, agronomy, harvesting and processing of *Grindelia*

Hedysarum

Hedysarum alpinum L. var.
americanum Michx

Family: Fabaceae (Leguminosae)

Common names: American hedysarum, American sweet-vetch, Alpine hedysarum, Alpine sweet-vetch, Sweet broom, Purple hedysarum

Scientific pseudonyms: *Hedysarum americanum* Michx. Britt., *Hedysarum flavescens* Regel et Schmalh

Hedysarum alpinum is a common species on the Prairie provinces whose name is derived from the Greek words "hedys" (sweet) and "aroma" (a spice or sweet herb). This unassuming sweet-smelling herb, whose presence is ubiquitous throughout Saskatchewan, has recently been the topic of some scrupulous scientific study. It has locally been investigated as a possible forage as it possesses good potential as an early forage legume crop. It also harbours a component which appears to act as a potent biological response modifier with both antitumour and antiviral effects (Guha et al. 1996); most notably against herpes simplex virus and HIV.

Description & Habitat

Hedysarum is a tufted herbaceous perennial, 15-80 cm in height, with moderately-leafy, branching erect stems (Bassendowski et al. 1989). Its leaves are compound, formed of 15-21 oblong leaflets with sparse grey hairs and prominent veins along their underside (Johnson et al. 1995). It grows from a stout, woody taproot which forms nitrogen-fixing root nodules.

Hedysarum begins to grow in May before other perennial legumes and produces flower buds in June. These flower through July to produce several clusters of pinkish pea-shaped flowers at its stem tips which are highly attractive to

honey bees. The fruit is a flat pod which usually has 3-5 internodes separating the seeds and are generally hairless except perhaps on the margins. Seeds are kidney-shaped, 3 mm long, and brown to purple-black in colour (Currah et al. 1983). These generally ripen in July and August. At the late bud to early flowering stage, plant biomass is comprised of approximately 63% leaves. Plants can grow in groups of a few individuals to several hundreds (Williams 1990).

Hedysarum is a widespread circumpolar species present across Saskatchewan and common in moist open woods, meadows, slopes and disturbed areas. It is especially common in the Boreal forest and the Cypress Hills (Looman 1983). It can grow in a sunny position on a variety of soils: shallow, poorly developed, rocky, dry, calcareous soils or in cold, wet, acidic, organic substrates (Williams 1990).

Cultivation & History

Hedysarum species have been used as cultivated forage in several countries and grazed by all classes of livestock (Bassendowski et al. 1989). Hedysarum's growing scheme is considerably shorter than alfalfa, as alfalfa is rarely ready to harvest before mid-September (Bassendowski et al. 1989). Its extensive range has been broadly described as North America to North Asia (PFAF), occurring from Alaska through western Canada southwards and as far east as Labrador (Williams 1990). It is also cultivated in eastern Europe as a source of the pharmaceutical compound, mangiferin.

Hedysarum reproduces primarily by seed, which is assisted by honeybee pollination and long erect stems to aid in seed dispersal. Seed is sown as soon as it is ripe in the spring: stored seed should be pre-soaked for 24 hours in warm water (PFAF). Seeds have good viability with seed set in the field having a germination rate of 97-100%; a process further enhanced by seed scarification. Seedlings started in a greenhouse may be planted into permanent position as soon as they are large enough to handle. It is reported to strongly resent root disturbance, therefore transplantation once established is not recommended.

Hedysarum recovers slowly after cutting and produces little regrowth compared to alfalfa (Bassendowski et al. 1989). As well, seeds are

often difficult to separate from the pod, which tend to ripen unevenly and fragment when ripe.

Much research investigating the improvement of hedysarum production is currently conducted in Russia, where hedysarum is highly valued for its medicinal properties. Researchers are currently developing methods for the in-vitro production of Hedysarum tissues for large-scale multiplication and prolonged cultivation (Lyapkova *et al.* 1999).

Agronomic techniques are also being developed to maximize bioproductivity of biologically active substances in medicinal and essential oil plants including Hedysarum (Shain 1996). It is recommended that plants be grown in two stages using water, UV radiation and growth regulators to regulate growth. Growth is accelerated during the early vegetative phase in order to maximize plant biomass. In the last 7-15 days prior to harvesting, growth is inhibited to stimulate the accumulation of desired secondary metabolites. Such manipulated growth regulation has increased output of useful compounds by 15-85%.

The Native Plant Revegetation Guidelines for Alberta (dated June 1999) list that currently, there are no varieties of native hedysarum commercially available, although it is currently undergoing varietal development which is expected to be in commercial supply by 2003-2005 (AAFRD).

Products & Uses

• Food Uses

Hedysarum is a legume with many culinary uses, as described by Johnson *et al.* (1995): the young shoots can be eaten raw, boiled or roasted having a sweet licorice taste in the spring which, once cooked, tastes like young carrots. However, it is usually the roots which are consumed and can be prepared raw or cooked by boiling, baking or frying. The roots are dug from fall to spring, as long as the ground is thawed, but during the summer they become unpalatably dry and woody.

• Forage Legume

Hedysarum is also readily grazed by all classes of livestock; its strong woody taproots provide effective protection from mechanical injury and low-temperature damage (Bassendowski *et al.* 1989). Several hedysarum species make

excellent forage crops in Algeria, Spain and other Mediterranean countries.

As American hedysarum begins growth and flowering quite early in the spring, its potential as an early forage legume crop (particularly for northern prairie areas) was deemed worthy of investigation by Bassendowski and team of Agriculture Canada. In 1988, the researchers collected various seed samples of hedysarum from areas in central Saskatchewan to evaluate its nutritive value and potential use as a forage legume in Saskatchewan.

While protein and fibre quantities are similar to alfalfa, it is much higher in tannins than other forage legumes which effectively reduces its nutritive value and digestibility (Bassendowski *et al.* 1989). Its content of organic matter is significantly higher than alfalfa, but it is also markedly lower in organic matter digestibility.

• Medicinal Uses

Mangiferin, a compound derived from *Hedysarum alpinum*, is a main component of the antiviral drug Alpizarin which shows antiviral activity against the herpes simplex virus (Geodakyan *et al.* 1992). This drug also possesses cardiostimulant, capillary-strengthening, anti-inflammatory properties and enhancement of reparative processes in the gastric mucosa. Additionally, it has no significant action on the central nervous system, the tone of peripheral vessels and intestinal smooth musculature and fails to influence carbohydrate metabolism and blood coagulation system (Sokolov *et al.* 1988).

Mangiferin has also been found to possess other medicinally useful properties including:

- it has been found that mangiferin and its glucosides exert antidiabetic activity, with stronger activity than a synthetic antidiabetic drug, in mice by increasing insulin sensitivity (Ichiki *et al.* 1998)
- mangiferin enhanced tumour cell cytotoxicity in both normal and tumour-bearing mice macrophages (Guha *et al.* 1996); in vitro treatment of the splenic cells of tumour-bearing mice with mangiferin resulted in augmented killing of tumour cells
- mangiferin was found to antagonize in vitro the cytopathic effect of HIV (Guha *et al.* 1996)

- mangiferin has been found to inhibit the replication of herpes simplex virus type 2 (Zhu *et al.* 1993) whereas isomangiferin was found to be more effective than traditional control drugs acyclovir, idosuridine and cyclocytidine (Zheng *et al.* 1990)

Chemical Characteristics

Constituents

There do not seem to be any significant chemical analysis of *Hedysarum alpinum*. Reported compounds, however, include (Hetherington *et al.* 1997):

- mangiferin (~1% dry plant weight)
- isomangiferin
- hyperoside
- quercetin (Choi 1994)

Chemical analysis of Hedysarum constituents (Bassendowski *et al.* 1989):

	tannin (g/100g)	crude protein	organic matter
leaves	12.64	24.99%	58.94%
stems	6.32	12.87%	60.91%
whole plant	9.86	19.65%	59.71%
alfalfa	0.08	22.19%	72.80%

- its protein and fibre fractions were similar to alfalfa (Bassendowski *et al.* 1989); 6% and 3.1% respectively
- Hedysarum seeds have also recently been found to contain galactomannans (Smirnova *et al.* 1998).

Toxicology

Tannin content is found to be extremely high although, because of the tough epidermal layer, it is not expected to cause bloating in cattle. The tannins may be undesirable as they are thought to give a bitter taste and reduce intake (Donnelly *et al.* 1970).

Extracts

Water extraction produced a clear, yellow extract with a sweet, tea smell and an extractable yield of 22.8%.

Ethanol extract yielded a clear, light green extract with an extractable yield of 15.4%.

Solids were a black, sticky and oily solid with a strong, sweet odour.

Patents

Hedysarum does not seem constrained by very many patents; a total of three were found, of which none are specific for *Hedysarum alpinum*. They are listed as follows:

❖ 4518592 (85/05/21) Rusakova *et al.*
Process for preparing mangiferin; a process for preparing mangiferin and extracting xanthone glycosides from plants of the genus Hedysarum.

❖ CA1170572 (84/07/10) Cervelle *et al.*
FRANCE

Topical pharmaceutical composition with a total extract of *Hedysarum frutescens* Willd as a base; for treatment of virus disorders such as Herpes zona, H. varicella.

❖ CA2264201 (98/02/26) Joseph *et al.*
AUSTRALIA

Manipulation of proanthocyanidin biosynthesis.

Cost & Availability

Plant Part: Blooming aerals

Sask. Availability: This robust plant is abundant as a roadside herb in ditches that border native pasture and could be gathered in bloom in large quantities. Hedysarum blooms in late-May through early July.

Sask. Price:

Harvester Direct, whole: \$7/kg

Dealer's price, milled: \$8-11/kg

Note: Hedysarum, a legume, shows good potential for domestication and organic cultivation.

Potential suppliers:

♦ Parkland Botanicals, Togo Sask.
(306)597-2146

Recommended Resource:

M Bassendowski K.A., Drew Smith J. & Howarth R.E. 1989. The potential value of *Hedysarum alpinum* var. *americanum* as a forage legume for the northern Canadian prairies. *Canadian Journal of Plant Science* **69**: 815-822.

Hemp

Cannabis sativa L.

Family: Cannabidaceae (Moraceae)

Common names: Marijuana

Scientific pseudonyms: none current

Prior to the end of World War II, hemp made a significant contribution to the economic and social fabric of society and was used extensively for the fabrication of ropes, twines, tough thread, textiles, paper and more (AAFC 1994). During much of the 20th century, however, its production in many parts of the world ceased due to the criminalization of its production and utilization. However, recent times have witnessed the re-emergence of the hemp market with new applications in nutrition and industry. Strict legislation still poses an obstacle for the development of some products, as does its public vilification incurred over the last few decades. Yet the demand for hemp products continues to grow, as does research of its agronomy, product development and nutrition.

Description & Habitat

Hemp is a strong-smelling annual herb with a very long history of medicinal and fibre uses. Though the natural species is illegal to grow in many countries due to its narcotic properties, chemically-modified cultivars have been developed for commercial production. Most narcotic strains range from 3-5% THC (delta-9 tetrahydrocannabinol). It is postulated that THC and a complex of associated cannabinoid compounds, which are secreted by epidermal resin glands most numerous on and around the reproductive structures, protect the plant from UV-B radiation (Blade 1997).

The lower leaves are opposite and petiolate while the upper ones are alternate, petiolate and compound palmate with 3-7 acute, serrate leaflets (Chiej 1988). The plant is dioecious with

small inconspicuous flowers: the greenish male flowers are arranged in panicles and produce large quantities of pollen; the female flowers, also green, grow in leafy spikes in the leaf axils and are pollinated by wind (Bunney 1992). The fruit is a smooth, shiny, grey achene with a green seed. Seeds are ovoid, 5 mm long by 3 mm in diameter and are beige when mature.

Hemp has a taproot with numerous rootlets; in well-structured and well-drained soils, the taproot may penetrate 15 to 30 cm but in compacted soils the taproot remains short and the plant produces more lateral fibrous roots (Baxter et al. 1998). Hemp takes about 110-150 days to mature to seed.

Fibre hemp can reach heights of up to nine meters, but the usual average under commercial production is 2-4 m. The stem is erect, hairy, hollow and woody with an outer bark containing long, tough bast fibres. The centre core contains the hurds, or short fibres. The bark fibre are long with a high cellulose and low lignin content while the core contains short fibres high in lignin and low in cellulose. The value of the bark fibres is much higher than that of the core fibres therefore the value of hemp stems depends primarily on the proportion of bark in the stem. The proportion of bark depends mainly on the genotype (de Meyer 1994) but increases a little with plant density (Van der Werf et al. 1994).

Cultivation & History

It is believed that hemp originated in central Asia. There is evidence of hemp use as a food grain as well as for fish nets, clothing and rope 6,500 years ago in China (Blade 1997). Seeds have been located in North European funerary censors as early as 5 centuries B.C. (Duke 1985). Hemp also has much historical and current use as a narcotic: its action is almost entirely on the higher nerve centres and can produce an exhilarating intoxication with hallucinations (PFAF).

The first reports of hemp growing in the Americas is in Chile in 1545. Hemp was a popular crop in eastern and central Canada throughout the 18th and 19th centuries. During 1923-1942 there was an extensive research effort by the Canada Department of Agriculture to test agronomic management, processing and some crop improvement at approximately 30 locations across Canada. But in 1938, the Canadian government made the cultivation of

Cannabis sativa L. illegal through the Opium and Narcotics Act and agronomic research ceased. Since the Second World War, however, fibre hemp production has continued elsewhere with China, India, Russia and eastern Europe as the major centres of production (Meijer *et al.* AAFRD).

As of 12 March 1998, commercial production and processing of hemp was legalized in Canada. A license must be obtained from Health Canada which controls hemp production by legislation of the Controlled Drugs and Substances Act, ratified in 1996. Canada has adopted the 0.3% THC (delta-9-tetrahydrocannabinol) standards established by the European Union as the concentration which separates non-psychoactive strains suitable for legal fibre production from those which are illegally grown for their properties of intoxication (Blade 1997).

In 1998, Health Canada granted cultivation licenses to 32 Saskatchewan producers, which allowed production on 650 acres. While hemp was removed from the Noxious Weeds list to allow for the legal production of industrial hemp, its inclusion on the list was unnecessary anyway because it poses little threat to agriculture (Brenzil 1999). The Saskatchewan Hemp Association expects its members will grow a total of 3,000 to 4,000 acres of hemp in the 1999 production season.

The following industrial hemp varieties are approved by Health Canada Bureau of Drug Surveillance for commercial cultivation in 1999:

Variety	Origin
Anka	Canada
CS	Italy
Carmagnola	Italy
Fasamo	Germany
Fedora 19	France
Fedrina 74	France
Felina 34	France
Ferimon	France
Fibranova	Italy
Fibriko	Hungary
Fibrimon 24	France
Fibrimon 56	France
Futura	France
Kompolti	Hungary
Kompolti Hibrid TC	Hungary
Kompolti Sargaszaru	Hungary
Lovrin 110	Romania
Uniko B	Hungary

Hemp propagates mainly by seed which can remain viable for up to two years if stored in a cool, dry environment (Duke 1983). Rate of seed sown varies with the type of fibre desired: for coarse fibre for cordage and coarser textile, 2.5 bu/ha is used while for finest fibres, 7.5-10 bu/ha is used. When grown for seed oil, seeds are sown by drills and ensuing much-branched plants sometimes reach heights of 5.3 m with thick stems up to 5 cm in diameter (Duke 1983). For fibre, stems up to 2 m tall and 0.5 cm in diameter are best: larger stems tend to get woody and have lower fibre content.

Hemp seedlings are reported to be tolerant of light spring frosts, therefore seeding between May 10 and 15 should be relatively safe (for an excellent picture guide to seedling development, please refer to the following website: www.motherhemp.com). In research trials, hemp sown as late as June 12 has still provided grain yield. The advantage of early seeding should be in higher stalk and seed yield. The development of hemp crop is directly related to precipitation: as the amount of soil moisture decreases, and no further precipitation is available, the plants stop growing tall (Blade 1997).

Highest quality fibres are obtained by cutting at early flowering. Mower/conditioner and round-baler may be suitable for low to medium quality end uses. The best approach for harvesting grain appears to be direct combining when shelling becomes evident, running the header cutter bar 4-5 feet above the ground. After combining, the remaining stalk material can be cut and baled - mature stalk contains a coarse, low-grade fibre compared with stalk cut at early flowering, but should be marketable.

Hemp is quite susceptible to lodging, sclerotinia (*Sclerotinia sclerotiorum*) and bertha armyworms (*Mamestra configurata*). It is tolerant of light spring frosts and hard fall frosts will assist maturity by killing green leaf tissue remaining as the seeds mature. Hemp grows rapidly and soon outcompetes weeds; after plants are 20 cm tall, weeding is not necessary (Duke 1983). It performs well on a range of soil types, but is intolerant of poor drainage conditions - saturated soil will quickly cause stunting, yellowing and death of plants.

Initiating growers should expect 300-400 lbs/acre grain yield, while with experience the potential of current varieties could be in excess of 600 lbs/acre. In crops grown and managed

solely as fibre crops, yield of 10,000lbs/acre could be attainable (Manitoba Agriculture 1998). Fibres are best produced from male plants (Duke 1983).

For complete agronomic instruction, please refer to several related articles on the Alberta Agriculture, Food & Rural Development website (www.agric.gov.ab.ca/), 'Industrial Hemp Production in Manitoba' by Manitoba Agriculture Soils and Crops and other literature available at Saskatchewan Agriculture & Food Rural Extension offices.

Products & Uses

The most feasible possibility for the prairies in the near future appears to be production of hemp as an oilseed, with stalks as a secondary harvest (Manitoba Agriculture 1998).

• Fibre and Fuel

A process called retting dissolves the non-fibre portion of the bark and is necessary for extraction of the highest quality fibres. After retting, the stalks are mechanically decorticated i.e. the long fibres are separated from the hurds. Approximately one tonne of fibre can be decorticated from 3 to 4 tonnes of good quality dry straw. Without retting, decortication will result in fibre with a relatively high hurd content, which is suitable for applications not requiring the highest quality fibre (Moes 1996).

In Britain, a commercial company uses the hurd as an animal litter product and processes the bast fibre into mats which are used for bedding horses (Blade 1997).

Hemp could soon be grown in Ireland as the raw material for alternative power following success in trials at the Teagasc research station in Carlow. Research found that, in comparison to other alternative energy crops, cannabis provided a greater level of dry matter per hectare and provided easy to burn fibres (Daily Telegraph 1995).

Hemp is also re-emerging as a major raw material source for the clothing industry in Europe. Until now, hemp was used for making strong and sturdy fabrics like working clothes, uniforms, ropes and sails (etc.) but is now also being made into jeans, jacket, waistcoats, jewelry, hats and innumerable other products. Even designer houses such as Calvin Klein and Giorgio Armani have introduced hemp clothing into their lines.

• Oil Products

Hemp seed is a good source of oil that has been used historically for applications like paints and varnishes, as well as for edible purposes (Moes 1996). Hemp seed has potential as a relatively valuable specialty oil, primarily from a nutritional perspective, but also from an industrial perspective.

The aroma of hemp oil could be of considerable commercial value of evaluation of cultivars and development of extraction methods led to a pleasing scent in the resulting essential oils (Mediavilla *et al.* 1997).

The production of useful compounds such as stearidonic acid (produced by only a small number of plant species) and high levels of tocopherols (alpha, beta, gamma and delta) which have been identified as antioxidants, while some research has identified as anti-cancer compounds (Blade 1997). In particular, the good balance of desirable fatty acids and anti-oxidants in hemp oil suggest it is potentially high-value specialty oil (Moes 1996).

Perhaps the most interesting application of cannabis oil, especially for Saskatchewan, is its marked insecticidal activity versus larvae of different species of mosquitoes. Cannabis oil kills all mosquito larvae at concentrations ranging from 0.06-0.22ml/L (Chemical Weekly 1999).

• Pulp and Paper

In the 1960's, the specialty paper industry started using hemp as a raw material (Mathieu 1980; Meijer *et al.* AAFRD). Traditionally, hemp bast fibre is applied in specialty papers demanding high tear and wet strength, for instance, in cigarette and filter paper, nonwovens, security and art papers. Traditional chemical pulping process for fibre hemp was expensive, time-consuming and produced much polluting waste. New alternative pulping methods optimally exploit the high strength and low lignin character of the bast fibres produces pulp at a price that allows application in some segments of the bulk markets (Meijer *et al.* AAFRD). On laboratory scale, unbleached and bleached pulps were produced at about 80% recovery and at about half the energy inputs of mechanical softwood pulping. Hemp pulp is very competitive with the usual pulps when printing and writing paper application is taken into consideration (Capelle 1996).

In the Netherlands, recent research programs have dedicated over US\$9 million to determine whether fibre hemp can be used to develop and pulp and paper industry (Blade 1997).

• **Medicinal Uses**

Few plants have a greater array of folk medicine uses: alcohol withdrawal, anthrax, asthma, blood poisoning, bronchitis, burns, catarrh, childbirth, convulsions, coughs, cystitis, gonorrhea, lockjaw, malaria, snakebit, whooping cough and a many more (Duke 1983). Modern medicine uses cannabis to treat glaucoma and to alleviate the pains of cancer and chemotherapy (Duke 1983).

Four of its constituents are known antibiotics: cannabidiol, cannabigerol, cannabidiolic acid and cannabigerolic acid (Duke 1985). A beta-resorcylic acid has antibiotic and sedative properties, as well as antiviral effects. It also inhibits the growth of a mouse mammary tumour in egg embryo (Duke 1985).

Research has shown that cannabidiol may be a potentially useful therapeutic agent for treatment of oxidative neurological disorders such as cerebral ischaemic due to its potent antioxidant activity (Hampson *et al.* 1998).

Additionally, there is growing preclinical, anecdotal and clinical evidence that cannabis and individual cannabinoids are effective in suppressing some of the more troublesome symptoms of multiple sclerosis or the collateral effects of spinal injury, particularly spasticity and pain (Pertwee 1997).

• **Food and Nutrition**

The potential for hempseed as a food ingredients in industrialized nations, and especially in the US, matches or exceeds the potential for textiles (HFA). Hemp seed may be eaten raw or cooked, or can be parched and eaten as a condiment or made into cakes and fried (PFAF). The seed is quite tasty, but difficult to separate from the husk. There are four general methods for preparing food from hempseed: using the whole seed, using the hulled seed, milling the seed and using the oil directly (HFA).

Whole seeds are generally used as an ingredient in mixed seed or snack seed mixtures while dehulled hempseed has been described as the most significant hemp development in the last few centuries: it has improved palatability and eased processing (HFA). These can be used in

recipes much like sesame or tofu and when milled into a paste, it becomes a peanut butter-like delicacy long prized in eastern Europe. Milled seed are used in breads and cookies while the oil is included in fat-based products such as frozen desserts or baked goods (HFA).

HempNut is a hulled hempseed product which is organically grown, THC-free and one of the most nutritious products available. It can be consumed as a snack or used as an ingredient.

Hempseed meal has recently found a use in the brewing of specialty hemp beers. Hempen Ale, a product of Frederick Brewing Co. (pictured below from their website- www.hempenale.com), is advertised as a brown ale brewed with the seeds of the hemp plant providing a creamy head and a mellow, herbal flavour and aroma. Several similar products have also recently hit the markets.

• **Cosmetic Applications**

Hemp is an herb rich in essential fatty acids and amino acids, making it an ideal ingredient for soaps to creams, shampoo, healing salves and lip balm (WWD 1998). The seeds can be pressed to produce a protein-rich oil that's particularly well-suited to dry skin. There are many such products currently available. Notably, The Body Shop recently released controversial skin-care products for dry skin formulated with hemp. Though there were initial concerns that the line would be banned by Health Canada, it has since had unprecedented success (Bahadur 1998).

As illustrated below, Azida Inc. based in Elfrida Arizona is producing a variety of hemp oil-based body care products including shampoos and conditioners, lotions, sunscreen, shower gels and lip balms.

Chemical Characteristics **Constituents**

Fatty acid composition of seed oil (% of oil) of the hemp variety Zolotonosha 11 versus canola (Moes 1996):

Fatty Acid	Zolotonosha 11	Canola
myristic	0.03	n/a
palmitic	6.23	4
palmitoleic	0.17	n/a
margaric	0.10	n/a
stearic	2.80	2
oleic	11.9	55
vaccenic	1.07	n/a

linoleic	55.0	26
alpha linolenic	2.87	n/a
linolenic	16.4	10
arachidic	0.87	n/a
eicosenic	0.40	2
behenic	0.37	n/a
lignoceric	0.20	n/a
nervonic	0.10	n/a

Seed constituents dry weight/100g and fresh weight/100g (Duke 1985):

	Dry weight	Fresh weight
moisture	0.00 g	11.2 g
calories	487	421
protein	31.4 g	24.3 g
fat	29.6 g	28.0 g
carbohydrate	31.9 g	31.2 g
fibre	23.5 g	19.6 g
ash	7.1 g	5.35 g
calcium	139 mg	120 mg
phosphorus	1123 mg	970 mg
iron	13.9 mg	12 mg
vitamin A	518 mg	n/a
thiamine	0.37 mg	0.32 mg
riboflavin	0.20 mg	0.17 mg
niacin	2.43 mg	2.10 mg
vitamin C	0.00 mg	0.00 mg

Oil from the seeds contain (Duke 1983):

- oleic acid 15%
- linoleic acid 70%
- linolenic and isolinolenic acids 15%

Seed cake constituents (Duke 1983):

- water 10.8%
- fat 10.2%
- protein 30.8%
- N-free extract 40.6%
- ash 7.7%

Trigonelline occurs in the seeds while *Cannabis* also contains choline, eugenol, guaiacol, nicotine and piperidine; all listed as toxins by the US National Institute of Occupational Safety and Health. The cystolith hairs so characteristic of the leaves and perianth contain calcium carbonate.

Toxicology

Cannabis sativa pollen is classified as an aeroallergen causing allergic rhinitis, bronchial asthma, and/or hypersensitivity pneumonitis (Duke 1985). Oral ingestion of THC can cause muscular incoordination, dizziness, difficulty

concentrating and confusion while larger doses can result in catalepsy followed by coma and death from cardiac failure (Duke 1983). People working with the plant may develop dermatitis.

The safe maximum THC single dose is 70 mg/kg body weight and daily dose is 140 mg/kg; these doses do not result in any acute perceptible psychotropic or physical effect nor in any chronic adverse effects (Grotenhermen *et al.* 1998). Countries which have legislated THC limits in food include Switzerland and Canada.

Extracts

Extractive data is not available for hemp due to the lengthy requirement of a permit from Health Canada for research purposes.

Patents

Hemp, more than any other plant in this report, has a vast number of patents. The Japanese unexamined applications files database lists 510 patents, the US patent database lists 171, CIPO lists 191 and the European and World patent database no less than 95. Hence, all patents will not be listed herewithin if only for respect of the reader, but rather will be presented the patents with hemp in the title:

❖ 09947106 WO (99/09/23) Pierce D. US Quarternized hemp seed oil; for incorporation into cosmetic compositions such as shampoos, hair conditioners, hair sprays, mousses, gel pomades and skin creams.

❖ 00878536/EP A2 (98/11/18) Krubicza S. DENMARK

Alcoholic drink containing hemp constituents; spirits or mead based alcoholic drink comprising 2-3% vol.% hemp syrup obtained from hemp leaves.

❖ 00654215/EPB1 (98/08/12) & 00654215/EP A1 (95/05/24) Lamerant P. FRANCE

Biodegradable animal litter with hemp or flax in their mixtures; with excellent absorbing power, it does not release dust with beneficial effect on animal's respiratory tract

❖ 09745573 WO (97/12/04) Mierisch C.G. AUSTRALIA

Harvesting and processing green fibrous plant stalks; particularly *C. sativa* species.

❖ 09206043 (97/08/12) Ujita M. JAPAN
Hemp palm tea.

- ❖ 08284085 JP (96/10/29) Mitsushiba et al. JAPAN

Production of hemp pulp for casing use base paper.

- ❖ 00319589/EP B1 (95/11/02) Goto F. JAPAN

Thermoplastic composite material reinforced with hemp fibres.

- ❖ 07052602 (95/03/13) Keike et al. JAPAN
- Hemp composite yarn, cloth made of same and its production.

- ❖ D0356113 (95/03/07) Maggio J.
- Combined writing instrument and hemp leaf pocket clip.

- ❖ 00496689/EP B1 (94/08/31) & 00496689/EP A1 (92/07/29) Rasetti C. FRANCE

Thermal and acoustic insulation containing hemp byproduct and process for making same.

- ❖ 06166978 JP (94/06/14) Ohira et al. JAPAN

Production of bleached hemp pulp.

- ❖ 05025110 JP (93/02/02) Sakakibara et al. JAPAN

New compound and proteolytic enzyme inhibitor containing the same compound as active ingredient; said compound (lignaneamide isolated from *C. sativa* fruit) is useful as a treating agent for pancreatitis because of its excellent proteolytic enzyme inhibiting action.

- ❖ 05000822 (91/03/19) Hwang et al. KOREA
- Process for preparation of imitation leather from natural hemp.

- ❖ 04360653 (92/12/14) Kanehara et al. JAPAN

Production of eggs highly containing polybasic unsaturated fatty acid of hemp seed.

- ❖ 00387815/EP A1 (90/08/29) Rasetti C. FRANCE

Process for the treatment of a hemp byproduct, aggregates obtained by this process and concrete incorporating those aggregates.

- ❖ 01246440 JP (89/10/02) Nagashima et al. JAPAN

Multicolour-dyed hemp fibre structure and dyeing method for said fibre structure.

- ❖ 59101412 JP (84/06/12) Iida S. JAPAN
- Hair protecting cosmetic compounds containing the crude drug.

Cost & Availability

Plant part: seed only, stem only

Sask. Availability: Consolidated Growers and Processors (CGP) of Dauphin, Manitoba was established in 1999 to contract and process hemp seed and fibre. CGP has contracted with a few grower in Saskatchewan, but most of the growers are located in Manitoba.

Availability outside Sask.: As mentioned, a number of experience hemp growers can be found in Manitoba. Their primary crop is hemp seed and they consider the stem (or straw) a by-product.

Western Canadian Price:

Grower Direct, seed: \$1.20-\$1.50/kg

Grower Direct, baled stem: \$60-\$80/tonne

Certified Organic seed

Grower Direct: \$0.81/lb

Dealer's Price: \$1.25/lb

Potential Suppliers:

- ♦ Jim Pavlin, Dauphin Manitoba (204) 638-2448

- ♦ Sask Hemp Association (306) 757-4367

- ♦ Clayton Zylinskiak, Yorkton Sask. (306) 782-7219 - *Certified organic seed*

Labrador Tea

Ledum groenlandicum Oeder.

Family: Ericaceae

Common names: Bog labrador tea, Western labrador tea, Continental tea, James tea

Scientific pseudonyms: *L. latifolium* (Jacquin) Michx., *L. pacificum* Small, *L. palustre* L. spp. *groenlandicum* (Oeder.) Hulten

Labrador tea is a plant characteristic of northern Saskatchewan forests and recognizable by its rusty, woolly leaves. Its aroma is uniquely fragrant and enhances its utilization as a tea. Not much attention has been paid this plant as far as product utilization, and there appear to be no efforts at cultivation. The possibility of the multiple utilization of labrador tea raw material has nevertheless been demonstrated and justified by its chemical content (Belousov et al. 1998).

Description & Habitat

Labrador tea is a native evergreen shrub, 30-80 cm tall, with many branches, dense rusty hairs and a spicy fragrance. Leaves are alternate, oblong to narrowly oblong and 1-5 cm long. While a deep green colour above, these often drooping and leather leaves have a rusty underside with dense woolly hairs. Leaf edges are often rolled under. It has a rhizomatous root system that can reach depths of 15-50 cm.

Flowers appear from late May to early June in loose, umbrella-like clusters at its branch tips. They are white, 5-8 mm long with protruding stamens and long stalks. Labrador tea fruit are drooping, dry and finely-haired capsules which occur in clusters. They are 5-7 mm long and contain many seeds which ripen from late August through late fall.

Labrador tea is found in bogs, swamps and moist woods, an indicator of acidic nutrient-poor soils. The plant is widespread across boreal forest throughout Alaska, Canada and Greenland, north to Arctic coast.

There is much variation in the nomenclature of this particular plant and its close relative, *Ledum palustre* L. Some consider *Ledum groenlandicum* to be a subspecies of *Ledum palustre* and prefer not to differentiate it; *Ledum groenlandicum* becoming *Ledum palustre* ssp. *groenlandicum* (Belleau et al. 1993). However, the currently accepted scientific name for bog labrador tea remains *Ledum groenlandicum* Oeder (Coladonato 1993). Based on what is known about its chemistry, there do exist enough marked differences between the two plants to retain individual species status (Belleau et al. 1993). As well, although closely related, each exhibits significantly different rates of germination: 94% for *Ledum palustre* and a paltry 36% for *Ledum groenlandicum* (Karlin et al. 1983).

Cultivation & History

Labrador tea is found throughout eastern and northern North America and Greenland, and is also an ornamental and escaped species in Britain (PFAF). This plant has long been used by Native peoples of Saskatchewan and elsewhere to treat a variety of ailments. All cultivation of this plant seems to be by wildcrafting; there appear to be no efforts at cultivation.

Optimal substrate conditions for germination and establishment of labrador tea include a slightly acidic soil pH of around 5.5, mean daily temperatures greater than or equal to 17°C, little to no shading and constant moisture (Karlin et al. 1983). Labrador tea is often used as an indicator of acidic, nutrient-poor soils (Johnson et al. 1995), but prefers a moist humus-rich substrate. While it grows best in shade or semi-shade, plants flower more freely when grown in a sunny position (Huxley 1992).

Labrador tea reproduces primarily through vegetative sprouting from rhizomes, although it can also reproduce by seed (Krefting et al. 1974). Seed longevity is not pronounced, however, and germination is quite slow and variable (usually around 36%). Most seeds lose viability within a year (Karlin et al. 1983). Seed should be sown in a shady part of a greenhouse in February or March, while seed may also be sown in the autumn as soon as ripe (PFAF). Seedling may be separated as soon as large enough be handled and grown in a shady frame for 18 months prior to planting in their permanent position.

Labrador tea is said to grow best with certain fungal associations in the soil, therefore it is recommended to incorporate some soil from around well-growing established plants into the soil for new seedlings. The optimal planting density is 1700-4800 plants/acre (NPDC).

Labrador tea can be harvested any time of the year, although it is described as "least good" in midwinter (Elias 1980) when oil content tends to be lowest. Leaves should be collected in spring before flowering, while flowering tops should be collected during bloom. The composition of essential oil depends greatly on the vegetative period, plant part collected and can show significant qualitative variations (refer to *Constituents* section for more detail).

Products & Uses

Food Uses

The strongly aromatic leaves of labrador tea can be used to make a palatable tea (Coladonato 1993) that is high in vitamin C (Johnson *et al.* 1995). Leaves have also been used to put a head on beers (Johnson *et al.* 1995) and as a flavouring, particularly as a bayleaf substitute (PFAF). Dried labrador leaf is available locally in health food stores for use as tea. Pictured is a labrador tea product manufactured by Taiga Herbs from Darwell, Alberta and advertised on their website as "the one and only producer of Labrador tea in the world". While the substantiation of this claim remains questionable (as there are other locally available labrador tea teas), any attempts to locate other labrador tea products on the internet did indeed prove futile.

Folk Medicinal Uses

As a folk medicine, leaf tea is used to stimulate the nerves and stomach and in the treatment of asthma, colds and kidney ailments (PFAF). A syrup made from the tea is used for coughs and hoarseness. Externally, it is used as a wash for burns, ulcers, stings, and dandruff. Some also recommend labrador leaf tea as a sedative, especially if someone has had trouble sleeping (Johnson *et al.* 1995).

Dried and powdered leaves were also used by the Woods Cree as a diaper powder, with fresh chewed leaves applied to wounds as a dressing (Johnson *et al.* 1995). Further, the plant is believed to impart a mild narcotic and was

taken by Indian women three times daily shortly before giving birth (PFAF).

Insecticide & Repellent

The leaves have also been used to repel insects in cupboards and drawers; a strong decoction of the leaves can kill lice, mosquitoes, fleas and others (PFAF). Europeans used them to repel fleas, clothes moths and other insects, and they even put them in corn cribs to keep out mice and rats.

Anti-inflammatory

Research results indicate the possibility of making anti-inflammatory and reparative drugs from a 40% ethanol extract of leafy shoots of *Ledum palustre* L. and from the oilcake obtained after steam distillation of essential oil (Belousov *et al.* 1998).

Anti-radiation

Interestingly enough, a single injection of a dose of a combination of labrador tea and *Archangelica officinalis* extracts has been found to protect mice from fractionated gamma irradiation injury to both the gastrointestinal tract and the haemopoietic system (Narimanov 1993). Though interesting indeed, the practical applications of this finding remain sketchy.

Chemical Composition **Constituents**

Composition (%) of the essential oil of *L. groenlandicum* in various parts of the plants (Belleau *et al.* 1993):

Identification	Flowers	Buds	Stems
alpha-pinene	8.5	11.1	2.3
beta-pinene	7.8	9.4	3.6
sabinene	8.9	17.1	9.3
limonene	24.2	16.8	1.8
gamma-terpinene	2.5	4.1	5.8
bornyl acetate	2.3	5.5	6.0
terpinen-4-ol	2.3	5.5	13.1
beta-selinene	4.1	1.0	1.0
alpha-selinene	4.1	1.0	1.0
unknown	10.5	5.8	4.9

• Germacrene is associated with buds, alpha-pinene and sabinene with the flowering period and limonene with the flowers (Belleau *et al.* 1993). The composition of essential oil shows significant variations in quality seasonally and between individual plants.

Minor compounds identified in a sample containing 10% germacrone include (Belleau et al. 1993):

• linalool	0.11%
• omega-elemene	0.05%
• gamma-copaene	0.05%
• beta-bourbonene	0.15%
• beta-elemene	0.21%
• gamma-farnesene	0.18%
• omega-cadinene	0.21%
• guaiol	0.04%
• beta-elemenone	0.47%

Ledol was not found to be a constituent, as has been found in previous studies, although it is a major compound of the essential oil of *Ledum palustre*.

Composition of the essential oil of Labrador tea (Hetherington et al. 1997):

Compounds reported	Yield (%)
• Leaf essential oil	0.1-0.6 fresh weight
• germacrones	40-60% of essential oil
• sabinene	16-17%
• terpinen-4-ol	7.6%
• myrtenal	3.5%
• gamma-terpinene	3.2%
• alpha and beta-selinene	7.7-8.4%
• alpha-pinene	2.3-11.1%
• beta-pinene	2.9-9.4%
• gamma-elemene	3.5%
• bornyl acetate	3.3%

The possibility of multiple utilization of labrador tea raw material has been demonstrated and justified due to its coumarin, flavonoid and phenolic acid content (Belousov et al. 1998).

Toxicology

Although most people consider this tea safe for regular use, it can be toxic if large amounts are taken. Therefore, it is probably best to use labrador tea in moderation. It contains andromedotoxin, which can cause headaches, cramps, indigestion and other problems (Johnson et al. 1995). The USDA rates labrador tea as having no toxicity (NPDC).

Extracts

Water extraction of labrador tea leaves yielded a sweet smelling, slightly opaque extract with a light brown colour accentuated by a reddish-orange tinge. Filtration of the extract required cheesecloth. The extractive yield was 22%. Water-extracted solids are a crystalline solid with an orange-brown colour. Its aroma is more pleasant than that of the alcohol extract.

Ethanol extract yielded a clear, near-brown, dark yellowish-green extract with an extractive yield of 26%. Ethanol-extracted solids are a crystalline solid with a khaki green colour with a strong, sweet smell that is slightly tea-smelling.

Patents

Only one patent could be found for Labrador tea; a Canadian patent filed in 1994. The US PTO found no records for either "Labrador tea" or "Ledum".

♦ CA2137109 (96/06/02) Lingar W.
CANADA

Preparation containing extracts of Labrador tea, Rhodora, Sheep laurel and Leatherleaf; a herbal remedy for treatment of eczema, lichen planis, parvo virus and mange mite.

Cost & Availability

Plant part: leaves

Saskatchewan Availability: This low shrub grows in boreal forest as understory in black spruce bogs. Also found in open muskegs. Labrador Tea leaves are currently harvested by some aboriginal communities for use in ceremonial beverages. The forestry branch of Saskatchewan Environment classes this as a common plant and issues \$2 permits for the harvest of up to 1,150 kgs.

Saskatchewan Price:

Harvester Direct: \$11/kg

Dealer's Price: \$15/kg

Note: Material harvested in June while plant is blooming will have noticeable differences in essential oil quality and quantity. Flowers are often blended in tea mixtures. Labrador tea usually contains the chemical compound andromedotoxin that, in large doses, can cause headaches, cramps, paralysis, intestinal problems and intoxication. To prevent adverse effects, beverage labels should note the importance of limited consumption and short (less than ten minutes) steeping times.

Potential Suppliers:

- ♦ Parkland Botanicals, Togo SK.
(306) 597-2146
- ♦ Buck Enterprises, Le Pas Sask.
(306) 623-5932

Milk Thistle

Silybum marianum (L.) Gaertn.

Family: Asteraceae (Compositae)

Common names: Blessed thistle, Our Lady's thistle, Thistle of the Blessed Virgin, Marian thistle, Holy thistle

Scientific pseudonyms: *Carduus marianus* L.

Milk thistle has extraordinary medicinal uses substantiated by a long and rich ethnobotanical history and supported by a litany of scientific data verifying its antioxidant, antifibrotic, anti-inflammatory, antihypercholesterolemic and hepatoprotective properties. In Germany, it is a commonly prescribed herbal medicine for diseases of the liver. Further, milk thistle has recently demonstrated exceptionally high and novel chemopreventive effects, suggesting that milk thistle could be a useful cancer preventive agent against human cancers of epithelial origin (Zi et al. 1997). With such a great demand for novel drug therapies and a successful cultivation history, milk thistle has great potential as a medicinal crop.

Description & Habitat

Milk thistle is an introduced annual or biennial herbaceous weed which can grow easily on dry, rocky soil and attain a height of 6 feet. Milk thistle has a glabrous or slightly downy stem which is erect, branched and 20-150 cm in height. The leaves are alternate, glossy, white-veined with strongly spiny margins (Morazzoni et al. 1995). The lower leaves are sessile, while the upper ones are clasping (Bunney 1992). Its flowers are hermaphroditic purple tufts; a tube-shaped receptacle with densely bristled-spines.

The fruits (or achenes) are shiny hard-skinned achenes which are generally brownish in colour and speckled with a white, silk-like pappus at the apex (Morazzoni et al. 1995). They are 6-7 mm long, much resembling sunflower seeds,

with an oily taste and a scarcely perceptible odour (Bissett 1994).

Seed sown during March or April will usually flower in the summer and complete its life cycle in one growing season; seed sown from May to August will normally wait until the following year to flower and thus behave as a biennial (PFAF). Even after removal of most of the leaf tissue from thistles at the rosette stage or leaves and stems at the flowering stage, plants recover enough to produce abundant seed (Davidson 1990).

Milk thistle can be found on roadsides, waste places and cultivated ground. Milk thistle plants growing in waste places are fast growing, have significantly higher biomass and more and larger heads than thistles in surrounding herbaceous habitats (Gabay et al. 1994). In Finland, milk thistle in cultured trials produces 33-65 tonnes/ha of fresh biomass and 8-10 tonnes/ha of dry biomass (Galambosi 1989). It is a drought tolerant plant that requires very little fertilization. It will often self-sow freely and spreads rapidly from shattered seed. Milk thistle is cultivated for ornament and naturalized throughout a large part of Europe and the Americas.

Cultivation & History

Milk thistle has been known since ancient times; it was mentioned by Theophrastus (IV century B.C.) with the name of *Pternix* and by Pliny (I century A.D.) with the name of *Sillybum* (Morazzoni et al. 1995). In the Middle Ages, milk thistle was cultivated in monasteries for medicinal purposes and its properties were documented in many early medical texts. It has also formerly been cultivated as a vegetable crop (PFAF).

Milk thistle is native to the Mediterranean region including southern France, Turkey and North Africa. It is now naturalized throughout much of the world including central Europe, North and South America, Asia and Australia. Saskatchewan has no naturalized populations (Barl et al. 1996). Currently, milk thistle is cultivated as an industrial crop in many countries: it is grown to a limited extent in northern Germany and California, but main production occurs in Argentina, China, Romania and Hungary (Bissett 1994). Its market demand is as a medicinal herb in France, Italy, United States, Germany, Hungary and Greece. As its demand in the United States

in particular is increasing, cultivation will become a necessity (Barl *et al.* 1996).

Seeds are sown in March and April, whence the plant will usually flower in the summer and complete its life cycle in one growing season. When sown from May to August, however, the plant will flower the following year and thus behave as a biennial (PFAF). For the cultivation of milk thistle as food, the best edible roots are produced from a May/June sowing while a spring seed sowing ensures a supply of edible leaves through the summer. Seeds are harvested in July-August, following blooming (Morazzoni *et al.* 1995).

In Egypt, researchers compared the oil yield of cultivated seeds versus those of wild plants. It was found that cultivated plants (under water treatment of 60% per field capacity) have the highest yield of total oil content (34%), of which 96% is unsaturated fatty acids (Hammouda *et al.* 1994). This compares to 90% in wild purple-flowered plants and 83% in wild white-flowered plants.

Milk thistle is readily cultivated; easy to start, troubled by few pests and can provide a mature crop in less than a year (Hobbs 1992). Milk thistle succeeds in any well-drained fertile soil, although it prefers a calcareous soil and sunny position (Huxley 1992). It is a drought tolerant plant that requires very little nutrients and whose seed can remain dormant for up to three years (Anonymous 1998).

However, some aspects of its production have proven problematic. First of all, its spiny constitution makes it difficult to cultivate and harvest. Secondly, its seed must be carefully harvested to ensure that milk thistle does not escape cultivation and become a serious noxious weed. In Bulgaria, the swath harvester is preferable to direct combining due to its greater reliability and improved quality of work (Todorov *et al.* 1990). It is recommended that if a crop is to be harvested by conventional combine harvester, an extended cutting table and rape knife should be utilized (Schunke 1992). Thus far, however, an effective mechanical harvester has yet to be developed (Gunner 1998).

Large-scale farming of milk thistle tends to produce a seed which is acceptably high in active constituents but disappointingly low in germination rate; yields of 1,000-2,000 lbs per acre are expected (Anonymous 1998).

Harvesting is the main labour requirement and is labour intensive, unless you can combine it which is done in commercial planting by modified combine (Anonymous 1998).

In-vitro cultivation of cotyledon sections has promoted the growth of plantlets for wide-scale cultivation. Young cotyledons are sown in a modified Murashige and Skoog medium where successive subculture (without growth regulators) can produce a multiplication rate as high as 20:1 (Radice *et al.* 1997).

Both row spacing and fertilization affect the seed yield of milk thistle. The highest seed yield is obtained from narrow spacing cultivation ranging from 20-50 cm (Omer *et al.* 1998, Omer *et al.* 1996, Omer *et al.* 1993, Schunke 1992, Foldesi *et al.* 1983). Seed yield is also increased by hand hoeing, although this requires approximately 28 hours of labour/ha (Schunke 1992). Nitrogen fertilizer application of 120 or 240 kg/ha significantly increases seed yield, but also affects the concentration of seed compounds. While the overall seed oil yield increased (along with silymarin yield), the percentage of fixed oil decreased slightly (Omer *et al.* 1998). There were no meaningful effects on seed flavonolignan content (Omer *et al.* 1993).

Products & Uses

• Medicinal Properties

Milk thistle is one of the most frequently prescribed herbal remedies in Germany where its clinical use is permitted (Gunner 1998). Its mainly medical uses include treatment of liver disease induced by alcohol, drugs or toxins, chronic inflammatory liver disease, liver fibrosis/cirrhosis and as an antidote for Ananita phalloides intoxication (Leng-Peschlow 1996). There are many liver remedies and choleragogues containing either the isolated active complex silymarin (i.e. Legalon™, Durasilymarin™) or standardized extracts (Bisset 1994).

Locally, milk thistle extract is available in capsule form (generally standardized to 80% silymarin content), as well as in a variety of products including a one-week herbal cleansing program, tinctures and as a juice (Schoenenberger Nettle Juice). Silymarin does not readily dissolve in water therefore milk thistle is generally not used as a medicinal tea.

The pharmaceutical properties of silymarin are so numerous that they are best represented in an abbreviated table (modified from Leng-Peschlow 1996):

Table 1: Pharmaceutical properties of silymarin on the liver with selected references

- Increase in cell membrane resistance
- Competitive inhibition of toxin uptake by liver cells (i.e. poisonous mushroom *Amanita phalloides* toxins) (Saba *et al.* 1976)
- Antioxidant and radical scavenger
- Inhibition of lipid peroxidation
- Anti-inflammatory (Dehmlow *et al.* 1996)
- Antifibrotic (Schuppan *et al.* 1995)
- Stimulation of protein biosynthesis
- Acceleration of liver regeneration (Leng-Peschlow *et al.* 1991)
- Anticholesterolemic effect associated with significant reduction in liver cholesterol content (Krecman *et al.* 1998).

Chemoprotective agent:

Topical application of silymarin has been shown to exert exceptionally high protective effects against photocarcinogenesis (Katiyar *et al.* 1997). As well, pre-application of silymarin to mouse skin prior to application of carcinogens resulted in almost complete protection in terms of tumour incidence (a decrease of 85%) as well as multiplicity (a decrease of 94%). Milk thistle produces a novel chemopreventive effect by inhibiting an endogenous tumour promoter (Zi *et al.* 1997). Silymarin is incorporated in cell membranes and increases their resistance against injurious influences, probably by changing their physicochemical properties.

Anti-hypercholesterolemic agent:

Silymarin has also illustrated significant anticholesterolemic effects parallel to those of the antioxidant hypocholesterolemic drug probucol, with an added increase in high-density lipoprotein, a change considered to be of added benefit (Krecman 1997). With hypocholesterolemic drugs in urgent demand, milk thistle provides a readily available and natural source of therapy.

• **Cosmetic Applications**

The use of silymarin as a free radical scavenger, inhibitor against lipid peroxidation, as well as an anti-inflammatory agent presents a potential application of these substances in dermatological therapy and in the cosmetic industry (Morazzoni *et al.* 1994). Such

preparations are used for counteracting the degenerative and aging phenomena of skin, for promoting healing processes and in the treatment of erythema and burns.

• **Food Uses (PFAF)**

All plant parts, including the root, leaves, flower buds and stem can be consumed either raw or cooked (although the very sharp leaf-spines can be difficult to remove). Leaves are an acceptable spinach substitute and have a mild flavour when young, delectable in salads. Stems are palatable and nutritious, used as asparagus or rhubarb substitutes and are best utilized in spring when young. The seeds contain starch, protein and an oil that is up to 60% linoleic acid (Barl *et al.* 1996), quite suitable for edible purposes. The roasted seed can also be used as a coffee substitute. Milk thistle also contains a proteinase with clotting activity used in the production of soft cheese (Fevereiro *et al.* 1986).

Chemical Characteristics **Constituents**

Milk thistle seed components (Bisset 1994):

- Silymarin: 1.5-3%
a mixture of flavanolignans including silybin (= silibinin), silychristin and silydianin
- Fixed oils: 20-30%
- Proteins: 25-30%
- Others: mucilage, saponins, histamine, essential oil, sugars, saponins, vitamins C, E and K. Flavonoids include: taxifolin, quercetin, dihydrokaempferol, kaempferol, apigenin, naringin, eriodictiol, chrysoeriol.

Fixed oil constituents (Bissett 1994):

- linoleic acid (~60%)
- oleic acid (~30%)
- palmitic acid (~9%)
- sterols (0.63%)
- others including cholesterol, campesterol, stigmasterol and sitosterol, tocopherol (0.038%)

Toxicology

Silymarin is non-toxic and it has no known LD₅₀ (Ely 1989). Even when administered in large doses (20.0g/kg mouse), silymarin is nontoxic and does not accumulate (Bisset 1994). In

humans, it is excreted primarily via the bile (20-40%) within 24 hours and also via the kidneys (3-7%) (Flory *et al.* 1980).

Topical application of silymarin at 6 mg dose applied twice weekly is devoid of any apparent toxicity (Zi *et al.* 1997). Adverse effects of ingested silymarin have been seen in only 1% of patients, mainly in regards to the gastrointestinal tract and not of a serious nature (Leng-Peschlow 1996). No contraindications or side effects are listed in the German Commission E monograph (Bissett 1994).

Extracts

Water extract of ground milk thistle seed produced a viscous, beige-brown extract with a spicy, sweet smell. Extractive yield was found to be 11.8%.

Ethanol extraction yielded an opaque, creamy yellow extract with a strong, pungent smell and an extractive yield of 40%. Extract solids are comprised of two fractions; a viscous, yellow oil and an orange-brown solid precipitate with no odour.

Patents

A search of patents for milk thistle revealed that the vast majority are registered in Europe, if not all. Only one patent was found on the US PTO, (which proved non-relevant) while most located in CIPO were of European origin. Patents tend to be of two types: methods of extraction beet seed oil or components (10 patents), or for the formulation of cosmetic compositions (5 patents). Additional patents include those for the treatment of liver disease, chemical coatings and plant regeneration methods.

❖ 09943336 WO (99/09/02) Henderson R. L-ergothioneine, milk thistle and S-adenosylmethionine for the prevention, treatment and repair of liver damage.

❖ 10218748 (98/08/18) Takagaki *et al.* JAPAN

Agent for reducing alcoholic smell in food and drink.

❖ CA1334006 (95/09/26) Gorler *et al.* GERMANY

Cosmetic and dermatological compositions including an extract of *S. marianum* rich in silymarin associated with essential fatty acids.

❖ 4323616 (95/01/19) Schreiner E. GERMANY

Composition containing nucleic acids and derivatives for regeneration of hair.

❖ 4323614 (95/01/19) Schreiner E. GERMANY

Composition containing plant extracts and phospholipids for regeneration of hair and stimulation of hair growth.

❖ CA1334005 (95/01/17) Sincholle *et al.* FRANCE

Cosmetic preparations containing an extraction of the fruits of *S. marianum* to oppose aging of the skin.

❖ 00589357/EP A2 (94/03/30) & CA2106624 (94/03/23) Schieder *et al.* GERMANY

Method to produce protoplasts from *S. marianum* and corresponding plant regeneration.

❖ 102689 (91/11/18) Soroceanu *et al.* ROMANIA

Extraction of silymarin from *Silybum marianum* fruit.

❖ 04997649 (91/03/05) & 00278809/EP A1 (88/08/17) Papaconstantin *et al.* FRANCE

Cosmetic or dermatological composition containing a *S. marianum* fruit.

❖ 151326 (90/08/09) Minorska *et al.* POLAND

Silybum marianum oil modified alkyl coatings.

❖ 04871763 (89/10/03) Madaus *et al.* DENMARK

Method of treating liver diseases using pure silibinin.

❖ 148146 (89/09/30) Minorska *et al.* POLAND

Preparation of silymarin-free oil.

❖ 148072 (89/09/30) Minorska *et al.* POLAND

Obtaining silymarin-free oil.

❖ 93783 (89/09/03) Marinica *et al.* ROMANIA

Extraction of silymarin from *S. marianum*.

❖ 1000468 (88/12/13) No author. ITALY

Process for extraction of silymarin from *S. marianum* with chloroform and acetone as solvents.

- ❖ 2613618 (88/10/14) Papaconstantin et al.
FRANCE

Skin composition containing extracts of *Silybum marianum* and essential oils.

- ❖ 04749573 (88/06/07) Bonne et al.
FRANCE

Cosmetic preparation useful for opposing skin aging containing an extract of the fruits of *Silybum marianum*.

- ❖ 3225688 (84/01/12) Suschnik M.
GERMANY

Recovery of silymarin from *Silybum marianum*.

- ❖ 04368195 (83/01/11) Madaus et al.
DENMARK

Method for extraction of silymarin from plants.

- ❖ 97285 (78/12/30) Kaczmarek et al.
POLAND

Concentrate with high silymarin content from *Silybum marianum*.

- ❖ 04081529 (78/03/28) Crippa F. ITALY
Polyhydroxyphenylchromanones.

- ❖ 89368 (77/06/30) Kaczmarek et al.
POLAND

Concentrate from *Silybum marianum* seeds.

- ❖ 03864484 (75/02/04) Madaus R.
Therapeutic composition and methods using silymarin comprising polyhydroxyphenylchromonones.

- ❖ 7391212 (73/11/28) Takemoto et al.
JAPAN

Silybonol from seed of *Silybum marianum*.

Cost & Availability

Plant part: seed only, blooming aerial (baled)

Sask. Availability: Some milk thistle has been grown in Saskatchewan on an experimental basis, notably near Langenburg Sask., but seed yield were discouraging. Another grow near Humboldt transplanted 1000 milk thistle seedlings in 1999 and is planning to expand production in 2000. Large scale production of milk thistle seed occurs in Bulgaria.

Sask. Price Seed:

Grower Direct, Conventional seed: \$33-40/kg

Seed Price outside Sask.: One bulk botanical supply house located in Ontario quoted \$18.75/kg for orders of 10 kg or more. Orders of ten tonnes (container loads) from Bulgaria can be landed in Toronto for approximately \$8/kg.

Sask. Price Blooming Aerials (baled):

Grower Direct, baled: \$200-\$400/tonne.

Potential Suppliers:

Seed and Bales

- ♦ Harold Theissing, Humboldt Sask.
(306) 682-3582

Seed only

- ♦ Global Botanicals, Barrie Ontario
(705) 733-2117
- ♦ George Triov ET Export Bulgaria
Telephone: ++359 48 942260
- ♦ Emerald Seed Productions Ltd. Regina, Sask. (306) 924-2033

Recommended Resources:

M Leng-Peschlow E. 1996. Properties and medical use of flavonolignans (silymarin) from *Silybum marianum*. *Phytotherapy Research* **10**: S25-S26.

- a very good and concise review of the pharmaceutical properties of milk thistle

M Morazzoni P. & Bombardelli E. 1995. *Silybum marianum* (*Carduus marianus*). *Fitoterapia* **66(1)**: 3-42.

- an excellent review of the pharmacology of milk thistle along with some information on its botany and chemistry

Red Osier Dogwood

Cornus stolonifera Michaux

Family: Cornaceae

Common names: Red willow, Western dogwood, American dogwood, Redstem dogwood, Red dogwood, Squawbush, Gutter tree, Shoemack, Dogberry tree (9 others are listed by the USDA)

Scientific pseudonyms: *Cornus alba* L., *Cornus sericea* L., *Svida stolonifera* (Michaux) Rydb., *C. pubescens* Nutt., *Thelycrania stolonifera* (17 others are listed by the USDA)

Red-osier dogwood is a very ubiquitous Saskatchewan species, even more so in winter when its bright red stems provide a splash of colour to the snow-covered landscape. This hardy shrub is a good specimen for cultivation as it is extremely hardy, self-propagating and fast-growing. While there is a market for its branches in the craft industry, there appear to be no more sophisticated manufacturing uses and no restricting patents.

Description & Habitat

Red-osier dogwood is an erect to spreading shrub, which typically grows in an upright rounded fashion to a height of 1-3 m and a width of 2 m (AAFRD). Its conspicuous bright-red young stems characterize the shrub, which turn greenish-grey to purple when older. It has opposite, dark-green ovate leaves (3-8 cm long) delineated by 5-7 prominent parallel veins which converge from the rounded leaf base towards the pointed tips (Johnson *et al.* 1995). Dense, flat-topped clusters of small white or greenish flowers appear in late May or early June and flower through until August.

Individual plants generally first bear fruit at 3 to 4 years of age, while older plants are more prolific (Smithberg 1974). White, occasionally blue or purple, juicy and globular drupes (5-6 mm across) are produced in August (Johnson *et al.* 1995). These are generally too bitter to

consume (Royer *et al.* 1996). Seeds have dormant embryos and require stratification for 1 to 3 months prior to germination. They can remain viable in cold storage for 4 to 8 years (Crane 1989). There are nearly 18,500 seeds per pound (USDA).

Red-osier dogwood has a thick, extensive root system for which it has been described as a rampant sucker. Even its lower branches sometimes root and form new plants (Royer *et al.* 1996). On good sites, red-osier dogwood can form dense thickets through vegetative reproduction (Crane 1989). Dogwood is common in woodlands, clearings and riverbanks throughout the prairies, preferring a moist soil and a position in the sun or partial shade (PFAF). Dogwood is a hardy species; easily grown and succeeding in any soil of good or moderate fertility (Chittendon 1951). It has a moderate to fast growth rate, ranging from 10 to 45 cm a year (AAFRD).

Red-osier dogwood has incited many scientific studies due to its extreme tolerance for cold (at least sixteen papers examine the cold hardiness of dogwood, most of them from the 1970's). In laboratory conditions, it has been shown to survive temperatures as low as -196°C (Crane 1989). Dogwood can avoid freezing injury by freezing its water content extracellularly, rather than within precarious living protoplasm (Newton *et al.* 1989).

An extensive review of literature and study has given red-osier dogwood the scientifically correct name of *Cornus sericea* (Eyde 1988), although *Cornus stolonifera* remains a commonly used scientific moniker in several texts.

Cultivation & History

Red-osier dogwood is native to North America, ranging from Alaska and the Yukon through to Labrador and Newfoundland. It is a dominant understory shrub in the early successional willow and balsam poplar forests. Dogwood has further been naturalized in Britain as an ornamental species. Although it can grow on a variety of soil, it prefers rich, moist, moderately acidic to neutral soils (pH 4.8-7) in 75% full light. The optimal planting density is 1100-2700 plants/acre (NPDC).

While seed production and handling have been described as "very good" (Plummer *et al.* 1977), seed germination is anything but. Red-osier dogwood is not being used to its full potential

because of unpredictable and low germination rates even under controlled growth cabinet conditions (Fedkenheuer *et al.* 1980). Raising bare root or containerized stocks in nurseries, which requires rapid and uniform seed germination, is a challenge with this species (Acharya *et al.* 1992).

Acharya *et al.* (1992) set about trying to determine whether any environmental conditions contributed to the high variability of seed germination observed in red-osier dogwood. The only correlate found to be significant was the source population: germination success is mostly influenced by very irreversible genetic factors. It was concluded that to maximize seed germination in this species, seeds must be selectively collected from populations with high germinability. Seeds are best sown as soon as ripe, but they must be separated from the fruit since they contain germination inhibitors. Stored seed can remain viable in cold storage for 4-8 years. They should be cold stratified for 3-4 months and sown as early as possible in the year; scarification may also accelerate germination which, especially of stored seed, can be very slow taking as long as 18 months or more. The slow germination of seed clearly reflects the importance and success of vegetative reproduction in dogwood propagation.

Cuttings of red-osier dogwood have been found to root easily without any special treatment and can be directly planted providing that sufficient moisture is available. Cuttings are more quickly established when taken in the fall: 100% of cuttings taken in early August were rooted in 5 weeks while 90% of those taken in mid-April rooted in 8 weeks (Doran 1957). However, rooted cuttings should preferentially be planted in early spring before May - not after June 1 (Crane 1989). Rooted hardwood cuttings are taken in January, allowed to develop callus in refrigerated storage, and planted in mid-May in well-drained soil 2 inches apart (USDA).

Products & Uses

• Bioremediation

The primary use of this species is for streambank protection. Dogwood is especially valuable for protecting and stabilizing streambanks because of its root system (Crane 1989). It is well adapted to disturbed sites, excellent at stabilizing soil, easy to establish

and grows rapidly. It has potential for use in erosion control and greater potential for long-term revegetation (Dittberner 1983).

• Medicinal and Food Uses

An extract from red-osier dogwood, such as bark tea, has been used as an emetic for treating fevers and coughs (Mozingo 1987). Many tribes have scraped or shaved off the green inner bark, dried the pulp, and used it for smoking either alone or mixed with tobacco (Johnson *et al.* 1995). The powdered bark has also been used as a toothpowder to keep teeth white and gums healthy (Grieve 1931).

Fruits can be eaten raw or cooled and are described as juicy, bitter and unpalatable (PFAF). As well, an edible oil can be derived from the seed. Red-osier dogwood has been rated fair in energy value and poor in protein value (Dittberner 1983).

• Additional Uses

There is a market for dogwood as a dried and preserved floral in floral and handicraft industry where it is a popular wood for constructing wreaths (Bart *et al.* 1996). A fibre obtained from the bark is used as cordage while dyes can be obtainable from the bark and roots. There are apparently no more sophisticated manufacturing uses.

Chemical Characteristics

Constituents

The nutrient composition in the leaves and stems of red-osier dogwood show seasonal variability, albeit slight (James *et al.* 1978). Concentrations of magnesium and calcium show a July peak with potassium peaking in June. Nitrogen and phosphorous both decline from early spring to midsummer but by September, levels are returned to April values.

Leaf protein characteristics (Roath *et al.* 1982):

- | | |
|-------------------------|--------|
| • Crude protein content | 13.44% |
| (% of dry matter) | |
| • Apparent protein | 16.27% |
| digestibility | |
| • Digestible protein | 2.19 g |
| in feed (g/100 g) | |

Berry constituents (Usui *et al.* 1994):

- | | |
|--------------|--------|
| • moisture | 76.38% |
| • dry matter | 23.62% |
| • fat | 3.58% |
| • protein | 1.77% |

- carbohydrates 2.60%

The bark contains cornic acid, similar to acetyl salicylic acid (ASA), but not quite as strong (Willard 1992). Other reported compounds include:

- quercetin, hyperin and kaempferol (Hetherington *et al.* 1997)
- cornoside and halleridone (Stermitz *et al.* 1998); also noted was a lack of iridoid glycosides

Tannins in the leaves appear to inhibit protein availability, but there appears to be little or no inhibition of protein availability in the stems browsed in the winter (Roath *et al.* 1982).

Toxicology

Highly active constituents are not known to be present in the family, and the iridoid cornin (also known as verbenalis) which is located in the leaves, has little toxicity (Bissett 1984). No toxicity is listed by the USDA (NPDC).

Extract

Water extraction of the flowering asexuals, leaves and twigs of red-osier dogwood produced a clear golden orange extract with a sweet, deep tea aroma and yielded 25.3% extractable solids. Dried solids are a crystalline solid of a brown-orange colour and a very sweet scent.

Ethanol extraction yielded a bright green extract which was easily filtered and had an extractable yield of 23.9%. Dried solids are a slightly orange-tinged black colour and are slightly sticky with a bitter smell.

Patents

That red-osier dogwood has undergone little product development is evident in its lack of patents. While there are patents for dogwood or *Cornus*; these are all for cultivars (mostly ornamental) under Plant Protection (PP) patent. There are two patents in the CIPO for other members of the *Cornus* genus:

- ♦ CA2206012 (98/11/23) Yoon *et al.*
CANADA

Novel compounds for the treatment and prevention of diabetes; extracts from medicinal plants, including *Cornus officinalis*, for the

prevention, treatment and cure of type II diabetes.

- ♦ CA2106097 (92/09/15) Bonte F. FRANCE
Cosmetic or pharmaceutical, especially dermatological, composition containing oxyacanthine in particular for stimulating hair growth or retarding hair loss; utilizing *Cornus florida*.

Cost & Availability

Plant part: leaves and twigs

Sask. Availability: This shrub is very widespread as understory vegetation in stands of trembling aspen and white birch. It prefers moist sites such as north-facing slopes and hollows in the aspen parkland and mixedwood forest eco-regions. The bark of this shrub is harvested and blended as an ingredient in Native American ceremonial smoking mixtures.

Sask. Price:

Direct from harvester, whole: \$9/kg

Dealer's Price, milled: \$12-\$14/kg

Note: Harvest season for this botanical is July-September.

Potential Suppliers:

- ♦ Parkland Botanicals, Togo Sask.
(306) 597-2146
- ♦ Buck Enterprises, Le Pas Manitoba
(204) 623-5932

Reindeer lichen

Cladina stellaris (Opiz) Brodo

Family: Cladoniaceae

Common names: Northern reindeer lichen, Star reindeer lichen, Caribou lichen, Silver moss, Reindeer Moss

Scientific pseudonyms: *Cladonia stellaris* (Opiz) Pouzar & Vezda, *Cladonia alpestris* (L.) Rabenh., *Cladina aberrans* (Abbeyes) Hale & W.L. Culb.

Lichens have been used as medicinal and nutraceutical agents since ancient times (Correche et al. 1998). The abundance, uniform colouring and handsome appearance of reindeer lichen in particular, has also made it a valuable and economically attractive commodity in the floral and craft industry (Kauppi 1979). Despite a history of fragmentary research, the reindeer lichen component usnic acid has recently gained increasing notoriety for its antibacterial, antifungal, antiviral, insecticidal and antitumour-cell properties.

Description & Habitat

Reindeer lichen is an upright, densely branched shrub lichen. It grows in compact, rounded heads, 5-10 cm tall, which can grow singly, in small clumps or form billowing mats with a yellowish-white to pale yellowish-green colour (Johnson et al. 1995). While it has no main stem, its 4-6 uppermost branches form a whorl of interwoven branches which form the bulk of its body. The branches are hollow and dull; its appressed cottony surface has a spider-web like texture.

Reindeer lichen is found on soil, trees, humus or thin soil over rocks and is widespread throughout the boreal forest. It most commonly occurs on moist, sandy, nitrogen-poor soils, on shallow humus layers or dry peat (Tesky 1992). It will often form extensive, thick mats on the boreal forest floor. The surface dries quickly, forming a crunchy upper layer but below this the lichen can remain moist for long periods (Johnson et al. 1995). Reindeer lichens have

been found on sites with acidic pH values ranging between 4.5 and 5.5 (Scotter 1971). As they are able to obtain moisture from the air, reindeer lichen can colonize soil too dry for vascular plants and thus become a dominant floral element. As such, reindeer lichen commonly occurs as the dominant or codominant ground cover on open sites dominated by white spruce, black spruce, paper birch or jack pine (Tesky 1992).

The most widely accepted genus name for reindeer lichens is *Cladonia* Wigg (subgenus *Cladina* (Nyl.) Vain, but some authorities still separate the reindeer lichens into the genus *Cladina*. Taxonomic representation in text will vary greatly. As well, several lichens are also referred to as reindeer lichens: green or yellow reindeer lichen (*Cladina/Cladonia mitis* Sandstrom), grey or true reindeer lichen (*Cladina/Cladonia rangiferina* (L.) Nyl).

Reindeer lichen derives its name, not surprisingly, from being a main dietary staple of caribou and reindeer. In Europe, the Finnish-Russian border can be clearly distinguished by satellite image composite by the heavy lichen grazing (Vare et al. 1996).

Cultivation & History

Reindeer lichen is a common lichen found through much of North America and northern Europe. Most of its cultivation occurs in Finland and Norway, where its export to central Europe is a major economic industry.

It is a very slow-growing species therefore collection should be carefully managed such that it is not depleted. At the Taltson River Region in the Northwest Territories, *Cladina stellaris* has an average annual growth rate of 3.4 mm per year (Scotter 1963). It has more lateral branching than other reindeer lichens, therefore can produce more forage annually despite a lower annual linear growth rate (Miller 1976). Reindeer lichen recovers poorly from disturbance and can take up to 15 years to recover from heavy grazing by caribou.

Cladina stellaris is generally shade-intolerant and is a late-seral to climax species - meaning that it establishes late in succession following a fire or major disturbance (generally after 30-100 years). As it is predominantly found in white and black spruce stands, optimal cultivation activity presents itself in clear-cut forest stands. In such an area, new species will recolonize and

out-compete *Cladina stellaris*, therefore reindeer lichen may be ethically removed without fear of disturbing the ecosystem.

The dispersal of reindeer lichens occurs primarily by means of thallus fragmentation and to a much smaller extent by ascospores or seeds (Tersky 1992). Reindeer lichens grow vegetatively by annually producing new growth at the top of the podetium, which lengthens the internode formed in previous years (Ahti *et al.* 1967).

Lichen thallus fragments can be maintained in growth cabinets and grown successfully (Fahselt 1981). The greatest success in culturing lichens in glasshouses is under natural light regimes or in growth chambers with at least 2500 foot-candles of illumination (Dibben 1971). Levels of usnic acid and atranorin do not vary in differing conditions of light intensity, although perlatolic and fumarprotocetraric acid per unit dry weight of thallus were found to be dependent upon light availability.

Most reindeer lichen is hand collected by wildcrafters. The lichen may be gathered whenever the found is free from snow, though in practice, the season is generally from mid-May to early November (Kauppi 1979). In dry weather, collection is only possible after watering, a practice increasing in popularity as it ensures continuity of operations irrespective of the weather. The lichens are then packed in trays and stacked for drying.

Products & Uses

• Floral & Craft Products

Cladina stellaris is of high commercial value because it can be used in diverse flower arrangements (Hausen *et al.* 1993). Architects and model railway enthusiasts often colour small pieces of reindeer lichen soaked in glycerine to make lifelike miniature trees and shrubs. In Finland and Scandinavia, this is the basis of a million-dollar export industry (Johnson *et al.* 1995), although the export to central Europe is restricted to four months between October and the end of January (Hausen *et al.* 1993).

• Nutritional Properties

While the nutritive value of reindeer lichens is rather poor, the content of digestible carbohydrates (mostly in the form of complex starches) is quite high and is therefore a good

source of energy (Tesky 1992). As well, while the protein, calcium, phosphorus and vitamin content are all poor, the nitrogen-free extract of these lichens is thought to be highly digestible.

• Medicinal Properties

Lichens have been used as medicinal and nutritional agents since ancient times (Correche *et al.* 1998). Some, including *Cladonia* species, were reputed to be effective in the treatment of pulmonary tuberculosis (Vartia 1973). Usnic acid, the most widely distributed lichen substance, is a yellow, crystalline and water-insoluble compound. It has been examined since 1948 for pharmacological and medicinal effects (Hausen *et al.* 1993).

Despite the interesting properties and therapeutic potential of this compound, the scientific literature has been extremely fragmentary (Cardarelli *et al.* 1997). Recently, however, there has been a flourish of investigative activity into these lichen metabolites. Usnic acid and its coumarin derivatives have shown the following properties:

- an effective analgesic and antipyretic agent (Okuyama *et al.* 1995)
- significant antimicrobial activity versus gram-positive bacteria (Correche *et al.* 1998)
- antifungal activity against a variety of organisms (Proksa *et al.* 1996)
- antimycobacterial activity versus a non-pathogenic organism with a similar sensitivity profile to *M. tuberculosis* (Ingolfssdottir *et al.* 1998)
- usnic acid has also recently been shown to have antiviral properties (Cardarelli *et al.* 1997)
- at low concentrations, usnic acid has displayed a capacity to stimulate cell metabolism in some biological systems (Cardarelli *et al.* 1997)
- usnic acid showed anti-tumour effects when tested against three different neoplastic human cell lines; at a concentration of 50ug/ml, usnic acid showed 40-70% inhibition of tumour cell proliferation (Cardarelli *et al.* 1997)

As explained in Ingolfssdottir *et al.* (1998), while usnic acid is moderately effective in the treatment of several diseases, it has not been pursued as a potential antimicrobial agent due to its poor water solubility and lower efficacy compared to antibiotics from other sources.

However, in light of the current difficulties encountered in the management of multidrug-resistant strains and the consequent urgent need for new antimicrobial agents, it is now considered worthwhile to re-investigate several lichen metabolites especially with respect to antimycobacterial activity (Ingolfssdottir *et al.* 1998). Due to its antibacterial properties, usnic has also been commercially utilized in deodorants.

• ***Insecticide and Germination Inhibitor***

Usnic acid provokes strong mortality as well as significant growth retardation of the pest insect *Spodoptera littoralis* larvae due to antifeedant activity and acute toxicity (Emmerich 1993). This suggests potential use as an antifeedant and insecticidal product.

Usnic acid also inhibits seed germination and root growth (Barbalic 1963). At a concentration of 50 ug/ml, usnic acid was found to completely inhibit germination of *Nicotiana tabacum* seeds (Cardarelli *et al.* 1997).

Chemical Characteristics

Constituents

Amino acid composition of *Cladonia stellaris* (Iacomini *et al.* 1985):

<i>Molar composition</i>	
• tryptophan	1.0%
• lysine	4.7%
• histidine	2.0%
• ammonia	1.4%
• arginine	3.9%
• aspartic acid	7.9%
• threonine	4.3%
• serine	4.4%
• glutamic acid	13.4%
• proline	3.5%
• glycine	4.5%
• alanine	5.5%
• half cystine	1.2%
• valine	4.4%
• methionine	1.5%
• isoleucine	3.2%
• leucine	5.8%
• tyrosine	3.9%
• phenylalanine	4.1%

Total	80.6%
• Protein	2.69%
• Nitrogen	0.43%

Major acid components (Fahselt 1981):

<i>(mg/16 mm³ of extract)</i>	
• usnic acid	56 mg
• fumarprotocetraric acid	70 mg
• atronorin	36 mg
• perlatolic acid	34 mg

Polysaccharide composition (Iacomini *et al.* 1985):

• nigeran	0.12%
• galactomannan	3.2%
• arabinitol	1.4-2.2%
• mannitol	0.3-0.4%

Additional components reported by Hausen *et al.* (1993) as present in low, sporadic amounts:

- rangiformic acid, pseudonorrangiformic acid, ventoric acid, proteins and sterols.

Chemical composition of *Cladonia* species (Ahti *et al.* 1967):

• carbohydrates	93.4-94.4%
• minerals	1.1-1.5%
• proteins	2.6-2.9%
• fat	1.8-2.2%

The documented chemistry of reindeer lichen is quite variable and appears to vary by geography, ecological conditions and age of the lichen. In Finland and northern Norway, levels of perlatolic acid in *Cladonia stellaris* decreased significantly with northern progression (Huovinen 1985). Differences due to the age of thallus portions were highly significant: quantities of extractable compounds and of usnic and perlatolic acid decreased markedly in older thallus parts (Fahselt 1984).

Levels of lichen products in *C. stellaris* in differing tissue ages (Fahselt 1984):

	<i>Young</i>	<i>Medium</i>	<i>Old</i>
Usnic acid	2.31	1.17	0.18
Perlatolic acid	0.37	0.21	0.07

Young tissues are taken from the distal 1-2 mm of the lichen branches; medium aged tissues are 3-4 mm to 1-2 mm behind the tips; old tissues are about 4-8 mm tissues behind the branch extremities.

Toxicology

Cladina stellaris has moderate sensitizing potency (Hausen *et al.* 1993). People sensitive to usnic acid develop lichen dermatitis, an unpleasant disease with itchy reddened skin, sometimes accompanied by pimples or scaliness. In a survey of lichen pickers in northern Finland, 30 of 164 (18%) respondents developed dermatitis on fingers and hands, although only two cases warranted medical attention (Salo *et al.* 1981). Cases have also been reported in people who received Christmas wreaths decorated with reindeer lichen.

Undoubtedly, usnic acid is one of the components which contributes markedly to the sensitizing potency of *Cladina stellaris* (Hausen *et al.* 1993). While usnic acid is not a potent sensitizer, its high concentration must be taken into consideration. Perlatolic acid is also identified as an allergenic constituent. While it has been reported that this constituent has only been isolated in European samples (Hausen *et al.* 1993), several other studies with samples collected in Ontario and Saskatchewan report its presence (Fahselt 1981; Fahselt 1984).

Compared with common sensitizers of occupational and environmental importance, however, these products play but a minor role (Hausen *et al.* 1993).

Extracts

Lichen substances are very stable to oxidation and heat; even after a year of storage at room temperature, neither the raw extract nor the purified lichen acids and atranorin showed patterns of degradation (Hausen *et al.* 1993).

Reindeer lichen collected near La Ronge was dried and ground into a very fine, light powder. Water extraction produced a clear (but slightly opaque) extract with a creamy, light yellow colour. It had a very rich, earthy and woody smell and an extractive yield of 3.6%. The residual lichen material had a sand/ash constituency and was spongy and fluffy.

Ethanol extraction produced slight opaque, dull yellow extract and an extractive yield of 8%. Residual lichen material much resembled the starting powder. Dried solids are a slightly sticky solid, mustardy-brown in colour with a woody/ash smell. While the liquid extract was concentrated, a solid precipitated in the expelling flask which was collected and dried.

This produced a fine yellow powder with a very faint, somewhat spicy smell.

Patents

Both the CIPO and US PTO databases yielded no results for a patent search for *Cladina stellaris* or the genus *Cladina* in general. Two patents were present in CIPO for *Cladonia*, however; both Japanese patents dealing with tissue culture (CA 1191465) or cell cultivation (CA 1256816) of lichens. The US PTO lists 20 patents for lichen: many are off-base entries with the general use not specified. The following patent may, however, be of interest:

♦ 5447721 (95/09/05) Miura *et al.*
Superoxide eliminating agent from lichen cultures; for use in cosmetics.

Cost & Availability

Plant part: aerials

Sask. Availability: This tall and distinctly shaped ground lichen grows in conjunction with other *Cladina* species. Growing in pronounced rings, it is the primary ground lichen species used in the preserved dried floral trade. It is best harvested as a salvage operation in conifer stands slated for clear-cut logging.

Note - If processors are buying *C. stellaris* exclusively for its usnic acid content, they would be well advised to purchase *Cladina* spp. since harvesting would be easier and faster. Price of *Cladina stellaris* is estimated at 5x that of *Cladina* spp.

Sask. Price:

C. stellaris aerials only:

Harvester direct, with pine needles: \$12-\$15/kg

Dealer's Price, cleaned: \$25-\$30/kg

Cladina spp. aerials:

Harvester Direct, with pine needles: \$2.50/kg

Dealer's Price, cleaned: \$5-\$6.50/kg

Potential Suppliers:

♦ David Audy, Prince Albert Sask.
(306) 764-0992

Sandbar Willow

Salix interior Rowlee

Family: Salicaceae

Common names: Sandbar willow, Narrow-leaved willow, Coyote willow, Basket willow, Slender willow, Acequia willow, Silvery desert willow

Scientific pseudonyms: *Salix exigua* Nutt., *Salix argophylla* Nutt., *Salix stenophylla* Rydb., *Salix longifolia* Muhl. non Lam. An additional nine synonyms are listed by the USDA whereas the Plants for a Future database lists a total of 48 possible synonyms.

Sandbar willow is one of the most common willow species in Saskatchewan and one of its many untapped botanical resources. Willows are both known and potential sources of many chemical components; rich in phenolic constituents such as flavonoids, tannins and salicylates (Newall et al. 1996) as well as a source for many "environmentally-friendly" wood products and craft items, herbal medicines and cosmetics. Further, it has been estimated that if willows were grown on but 10% of Canada's marginal farmland, the fuel could replace the energy potential of 10 nuclear generating plants and supply much of Canada's gasoline (Small 1999).

Description & Habitat

Sandbar willow is a very common native short-lived shrub or small tree, 0.5-5 m tall, which grows in dense thickets formed by vegetative shoot growth of its roots (Johnson et al. 1995). It has smooth, greyish branches which are silky and reddish-brown when young. Willow bark is approximately 1-2 mm thick with a glossy, greenish-yellow or brownish-grey outer surface, which is smooth and often shows faint longitudinal striations (Bissett 1994). It has an astringent and bitter taste.

Leaves are long and narrow, 5-13 cm long, and about ten times as long as wide. Edges usually

have distinct teeth and short stalks and its colour is described as being equally green on both surfaces.

Flowers occur as short-stalked catkins; staminate (male) or pistillate (female) flowers that are each produced on separate plants. Male catkins have protruding yellow stamens while the female ones are green (Bissett 1994). In most cases, catkins will appear before the leaves (Looman 1983). Sexual reproduction produces fruit containing numerous hairless, narrowly ovoid seed capsules, 4-7 mm long.

Seeds are not very viable and survive as little as a few days. Seeds older than one week rarely germinate (Ware et al. 1949), but can be successfully stored four to six weeks at 0-5°C given proper conditions including light (Brinkman 1974). Sandbar willow is also able to reproduce vegetatively by sprouting underground shoot buds (occurring on its lateral roots) and producing male or female clones (Uchytel 1989). This type of suckering is quite uncommon in willow.

Sandbar willow has a broad North American range from Alaska to New Brunswick, south to Texas. It forms thickets in estuaries and swamps and along sandy, gravelly or mucky soils in or along watercourses, often invading fresh sandbars in rivers and streams. Willow is a pioneer species: it is a vigorous, fast-growing species that paves the way for longer-lived woodland trees (PFAF). After its initial colonization, sandbar willow helps to stabilize the sand and gravel deposits allowing for other species to follow. Willows are sensitive to competition and intolerant of much shade therefore are eventually out-competed and replaced by cottonwoods or poplars later during succession (Uchytel 1989).

Sandbar willow is an important food source for many wildlife species including beavers and moose, both of whom inhabit moist habitats generally colonized by willow (Uchytel 1989).

Cultivation & History

Sandbar willow is native to North America and is one of forty *Salix* species listed in Budd's Flora of the Canadian Provinces (Looman 1987). The taxonomy of North America's willows remains imprecise as many species can interbreed or are highly variable. Sandbar willow will occur on a wide range of soil

textures, but usually grow on soils derived from alluvial or fluvial parent material of mixed geologic origin (Wasser *et al.* 1982). Preferred soil pH is 6-8.5 with a high moisture content and low fertility requirement (NPDC).

Willow bark has long been used as a medicinal for its analgesic and antiseptic properties throughout North America and Europe. Collection and export of willow bark is mainly from eastern European countries: the former Yugoslavia, Bulgaria, Hungary and Romania (Bissett 1994). Commercially available dried willow bark is generally non-species specific, although tends to be limited to those with higher salicin content (although this is not always the case in herbal products). Bark collection should be harvested from 2-3 year old branches (Bissett 1994). In North America, sandbar willow has traditionally been used mostly for its wood products. It was collected by the Woods Cree for construction of canoes and snowshoes, cordage and other various applications (Johnson *et al.* 1995).

Although harder to plant, rooted stock is recommended as the best means of propagation because it has shown higher survival rates (Uchytel 1989). Slips should be obtained from local native stands, cuttings should be planted 30 cm deep with 20 cm left above ground (Platts *et al.* 1987). Such deep planting allows for more rooting surface to extract soil moisture and provides higher amounts of carbohydrates as stored food reserves. Sandbar willow cuttings root along the entire length of the stem and will root in about 10 days (Platts *et al.* 1987). Optimal planting density is 700-1200 per acre (NPDC).

Willow seed is not very viable, perhaps as little as a few days, therefore should be surface-sown as soon as ripe in the spring (PFAF). Cuttings of mature wood (current year's growth) should be planted from November to February in a sheltered outdoor bed or planted straight into their permanent position along with a good weed-suppressing mulch (PFAF).

Dr. Liisa Tahvanainen of the University of Joensuu's Faculty of Forestry in Finland has done much research on the cultivation and plantation of the basket willow species *Salix viminalis*. The following cultivation information and pictures are from the website:
(<http://gis.joensuu.fi/research/paju/front.html>)

Willow plantations are established with stem cuttings about 20 cm long, which are soaked in water for about two days prior to planting. During the establishment year, the plantation is susceptible to drought and weeds therefore irrigation and weed control may be necessary. Planting density is ~18,000 cuttings/ha with the most efficient planting machines planting 4 rows at a time at a planting rate of 1 hour/ha. Soil moisture and sunshine will stimulate root penetration and shoot development.

Willow production is low in its establishment year with usually less than 1,000 kg/ha. After the first summer, the shoots are cut and the actual production period commences. Production is maintained by short rotation periods, approximately 3-5 years. It is possible to repeat harvesting a plantation without re-establishing it for about 25-35 years.

Willow is harvested in winter following leaf fall when the soil is frozen. When the shoots are harvested as whole stems, they are more easily stored. The most efficient harvesters are heavy self-powered machines which cut and chip the shoots on a loading platform. Direct chipping reduces costs considerably and takes about 3 hours to harvest a hectare.

Products & Uses

• Medicinal Uses

Willow bark is used to treat mild feverish colds and infections (influenza), acute and chronic rheumatic disorders, mild headaches and pain caused by inflammation (Bissett 1994). The British Herbal Pharmacopoeia lists its actions as anti-inflammatory, antirheumatic, antipyretic, antihidrotic, analgesic, antiseptic and astringent.

Little study has been reported for this species, although the pharmacological actions of salicylates are well-documented. Willow bark is the phytotherapeutic precursor of acetylsalicylic acid (Aspirin®) and in times when medicines have been in short supply, notable clinical results have been achieved with it (Bissett 1994). All willows produce salicin, which chemically is closely related to acetylsalicylic acid (Uchytel 1989). Salicin is cleaved by intestinal flora into saligenin which can be absorbed into the blood and oxidized by the liver into salicylic acid (Bissett 1994). The activities of salicylates include many of the

same as those previously listed above by the Pharmacopoeia.

Additionally, willow bark contains tannins which are known to have astringent properties, while *Salix* leaves have long been reported to possess antidiabetic properties (Sharaf *et al.* 1965). Willow bark extracts are components of many analgesics and antirheumatics, hypnotics, sedatives and gastrointestinal remedies (Bissett 1994).

• **Bioenergy Crop**

Willows are heartily being pursued as an environmentally-friendly, alternative energy source. Canadian scientists have developed hybrid willows as potential biomass crops for ethanol, pulp and the generation of electricity (Small 1999). It has been estimated that if willows were grown on but 10% of Canada's marginal farmland, the fuel could replace the energy potential of 10 nuclear generating plants and supply much of Canada's gasoline (Small 1999). The use of trees for fuels, although less efficient than crops, may be a more reasonable alternative for Canada, since the trees can occupy the huge areas of marginal land unsuitable for crops (Small 1999).

Willow plantations that are ready for harvesting have about 40,000-50,000 kg dry matter/ha with shoots about 5-6 m high and a diameter of about 3-5 cm at breast height (Tahvanainen UofJ). Once properly established, it is possible to gain annual yields of about 9,000-12,000 kg dry matter/ha. This equals to the energy content of 3.7-4.9 tonnes of oil.

The commercialization of willow bioenergy crops has the potential of growing into a valuable new industry (Proakis 1998). In the US, the international *Salix* Consortium organization, with resources from the USDA and the Department of Energy, has initiated the "Biomass Power for Rural Development" Project. An estimated 40-60 thousand acres of willow (in western New York alone) will be planted by 2010. Projected fuel sales of almost \$20 million annually are expected through generation of willow energy crop, with electricity sales derived from biomass fuels approaching \$135 million annually (ETDE). This project is the first cost-shared cooperative research and development agreement to grow energy feedstock willows and generate renewable electricity from this fuel (ETDE 1996).

A similar project is underway in Ireland, as discussed by Timothy Volk in *Willow Biomass News* (1998), although on a much smaller trial basis. One hundred acres of willow was grown and cultivated, shredded into wood chips and dried. A gasification process then converted the willow wood chips into methane, hydrogen and carbon monoxide (without wood combustion) which were cleaned and cooled to power a dual fuel gas and diesel engine.

The process produced about 100kW of electricity and 150kW of heat in the form of hot water, enough to supply 10-20 homes during peak demand. Each pound of willow wood chips produced about 0.5kW of electricity. This trial successfully demonstrated the benefits of willow production and use of biomass crops at a single site in a rural community.

• **Cosmetic Applications**

Willow bark has been used in hair tonics to increase circulation and stimulate the follicle and has found usage in hair conditioners, shampoos and rinses (D'Amelio 1999).

• **Wood Products**

Native Americans used the stems for basketry and bow making, and the bark for tea and fabric making to make clothing, bags and blankets (Lanner 1983). Small twigs can be used for toothbrushes and medium-sized branches for manufacture of "cane" chairs and other furniture items which are experiencing a craft resurgence. Shredded inner bark has even been used to make environmentally-friendly sanitary towels and babies' nappies (PFAF).

• **Food Uses**

Willow leaves have been used to make a drink somewhat like orange juice (PFAF). While sandbar willow's energy value is rated as fair and its protein value as poor (Dittberner *et al.* 1983), chemical analysis shows that its protein and phosphorus content is nevertheless higher than that of grasses, with young growth lower in crude fibre (Looman 1983). It remains an important forage for wildlife (especially moose and beaver).

• **Bioremediator** (Tahvanainen UofJ)

Willows consume a lot of water, grow rapidly and both tolerate and store heavy metals. As such, willow can be utilized as a vegetation filter to purify areas afflicted with high heavy metal content, waste waters, sludge or seepages. Willow can also be utilized in the reclamation of

nutritious waste sludge which can be used as a fertilizer.

Chemical Characteristics

Constituents

Common constituents of willow bark (Newall et al. 1996):

- Glycosides: (phenolic, 1.5-11%). Various phenolic glycosides including salicin, salicortin, salireposide, picein and triandrin. Acetylated salic, salicortin, salireposide, and esters of salicylic acid and salicyl alcohol may also occur.
- Salicylates: (calculated as salicin). Vary between species from 0.5-10%.
- Tannins: Condensed
- Others: Catechins, flavonoids.

There is reported to be no difference between the phenolic glycoside pattern of the bark and leaf (Newall et al. 1996). The latter is also reported to contain flavonoids, catechins and condensed tannins.

Toxicology (Newall et al. 1996)

No reported side-effects were located, although side-effects and signs of toxicity normally associated with salicylates may occur (including gastric and renal irritation, hypersensitivity, nausea, vomiting, etc.). Salicylate side effects are not to be expected with the amount of salicylate derived from the administered drug: possible gastrointestinal troubles are likely due to the tannins present in the drug (Bissett 1994).

Nevertheless, precautions associated with salicylate therapy apply to willow therefore individuals with a known hypersensitivity to aspirin, with asthma, active peptic ulceration, diabetes and other kidney or liver disease should be aware of the possible risks associated with the ingestion of willow products.

Irritating effects of salicylates may also be enhanced by alcohol, barbiturates and oral sedatives which have been documented to enhance salicylate toxicity as well as mark the symptoms of overdose. The use of willow should be avoided during pregnancy and

breast-feeding. No toxicity is listed by the USDA (NPDC).

Extracts

Water extraction of willow leaves and twigs produced a clear, light orange-brown extract with a slight, sweet grass/tea smell with an extractive yield of 24.4%.

Ethanol extraction yielded a yellowish-green, sweet smelling extract with an extractive yield of 29.1%. Solids entail a slightly iridescent khaki green solids with a tinge of yellow and a strong, fallen leaf smell.

Patents

There are a multitude of patents for willow; some may be specific to a particular willow species, many refer simply to a *Salix* spp in general (none have been found for *Salix interior* or *Salix exigua*). The CIPO database produces 29 patents when searched for "willow" and 7 for "Salix", the US PTO shows a total of 11. Listed below are patents which might prove of interest to manufacturing endeavours:

❖ 05980905 (99/11/09) de la Harpe et al.
US

Chromium polynicotinate compounds and uses thereof; a compound containing a salicin-containing herb useful for supplementing dietary chromium, decreasing blood glucose levels, decreasing serum lipid levels and increasing lean body mass.

❖ 5962030 (99/09/05) Fine S.A.
Dietary supplement and method of treatment for diabetic control; a cocktail including "standardized willow bark (aspirin)".

❖ 11080002 JP (99/03/23) Okano et al.
JAPAN

Preparation for external use for skin-preventing aging; containing salicin.

❖ 09852583 WO (98/11/26) Weisman B.
Natural composition for treating bone or joint inflammation; novel composition for treating mammals containing a herb of the genus *Salix* (one of three selected herb extracts).

❖ 10287582 JP (98/10/27) Inoue et al.
JAPAN

Suppressant for liberation of histamine comprising bark extract; lists *Salix bakko* Kimura as one of 13 possible bark sources.

- ❖ 09839018 WO (98/09/11) Shrivastava R. FRANCE

Plant extract composition, method of preparation and pharmaceutical compounds containing them.

- ❖ CA2261930 (98/02/05) Smallwood et al. UK

Frozen confectionery products; includes anti-freeze polypeptides derived from *Salix* or many other plants.

- ❖ CA2258781 (97/12/31) Sang C. UK
- Cosmetic composition; for regulation of oily/shiny skin with willow bark extract.

- ❖ 09268117 JP (97/10/14) Tokia F. JAPAN
- Composition for oral cavity; with extract of a plant belonging to *Populus* or *Salix* (Salicaceae).

- ❖ 09739732 WO (97/10/30) Kojima et al.
- Antimutagenic agent; uses dihydromyricetin as an active to suppress effects of environmental mutagenic substances (*Salix sachalinensis*).

- ❖ 99116426 (97/10/13) Okano et al. JAPAN
- Antiaging skin preparation containing salicin and alpha-hydroxy acids.

- ❖ CA2141126 (96/07/27) Lazarowych et al. CANADA
- Combinational drug for treating migraine and other illnesses.

- ❖ 1170572 (96/07/17) Zhu L.
- Preparation of medicated toothpaste.

- ❖ 05407454 (95/04/18) Cavalieri et al.
- Larvicidal lectins and plant insect resistance based thereon; *Salix* spp. one of 53 possible lectin sources which have been found to be larvicidal against a number of common insect pests of agricultural crops.

- ❖ 05165932 (92/11/24) Horvath F. HUNGARY
- Therapeutic composition against psoriasis.

- ❖ 89175932 (89/07/12) Kojima et al. JAPAN
- Antimutagenic dihydromyricetin from *Salix*.

- ❖ 4722843 (88/02/02) Vinson W.L.
- Moisturizing nutritive and healing skin cream; a composition including *Salix alba*.

- ❖ 63316711 JP (87/06/17) Hirao et al. JAPAN

Beautifying and whitening cosmetic using extractions of mature leaves of a salicaceous plant.

- ❖ 59134718 JP (84/08/02) Sawaguchi et al. JAPAN

Tacky plaster base; comprised partially of seeds of *Salix babylonica* containing salicin and populin.

- ❖ 03928584 (75/12/23) Hudson M.S. US
- Extracts from active tree saps for treating P388 mouse leukemia; *Salix longipes* is listed as one of 5 tree sap extracts.

There are also various patents for *Salix* describing various driers, bark stripping machines and methods for harvesting and bundling.

Cost & Availability

Plant part: Leaves and twigs, bark

Sask. Availability: At least nine willow species grow throughout Saskatchewan in moist sites, and are quite accessible along river banks, wet road ditches and slough margins in fields. Some people harvest willow stems for rustic furniture components and meat smoking operations.

Sask. Price:

Bark: dry, milled and bagged: \$3-\$4/kg

Leaves & twigs: dry, milled and bagged: \$8-\$10/kg

Note: Leaves and twigs available for harvest from June to September. Bark easily peels late May through June.

Potential Suppliers:

- ♦ Buck Enterprises, Le Pas Manitoba (204) 623-5932
- ♦ Parkland Botanicals, Togo Sask. (306) 597-2146

A special thank to:

- The University of Montana Riparian and Wetland Research Program for permitting the utilization of photographs from their marvelous website; (www.rwrp.umt.edu).
- Michael Clayton and the University of Wisconsin Virtual Image Homepage; (www.wisc.edu/botany/virtual.html)

Skullcap

Scutellaria galericulata L.

Family: Labiatae

Common names: Marsh Skullcap, Common Skullcap, Skullcap, Quaker bonnet, Helmet flower, Hoodwort, Greater Skullcap

Scientific pseudonyms: *Scutellaria epilobiifolia* (Hamilton)

Skullcap is a historical herbal fixture invariably described as a powerful, natural nervine. While there are several centuries' worth of usage to attest its medical validity, there is little scientific verification. Skullcap nevertheless has found numerous applications in the herbal and cosmetic markets and is a fledging crop on several farms in Saskatchewan. For such a small mint, it has garnered a lot of interest.

Description & Habitat

Marsh skullcap is a small herbaceous perennial with slender rhizomes, ranging in height from 10-60 cm (Johnson *et al.* 1995). It has an erect, four-sided stem which bears opposite, wavy-margin and very short-stalked leaves. These bear a hairless upper surface, but are adorned by short, blunt-toothed hairs on the lower. They are oblong and tapering with a heart-shaped base.

Blue, sometimes purple, flowers appear from July to September in upper leaf axils, either singly or in pairs. The flower petals are fused into an intricate two-lipped tube with a hooded upper lip. The name skullcap is derived from the shape of the flower: it resembles a military helmet with its visor raised that was familiar to many early colonists (AAFRD). Fruits consist of four yellowish and bumpy nutlets.

Skullcap is widespread throughout the prairies inhabiting stream banks, ditches and lakeshores.

Cultivation & History

Warm tea from the dried leaves of these plants have been used by herbalists for over 250 years to treat nervous disorders (Johnson *et al.* 1995). In the 1700's, skullcap became a well-publicized cure for rabies. *Scutellaria laterifolia*, known as mad-dog skullcap, is also cultivated for herbal use and contains the same flavonoid active; scutellarin. This species is more common in the United States where its use is more prolific than that of *Scutellaria galericulata*. However, mad-dog skullcap is not as common in Saskatchewan and is mainly limited to the south-east corner of the province. Although the two have similar properties and are said to have the same applications (Bown 1995), they do differ in essential oil composition. In most herbal texts and compositions, however, *Scutellaria galericulata* and *Scutellaria laterifolia* can be used interchangeably.

Although there are over 90 species reported species of skullcap scattered over different parts of the world (especially abundant in America), marsh skullcap is also predominant in Britain where it is one of only two native skullcaps. It is cultivated as a garden ornamental in both Europe and North America. Skullcap will succeed in any ordinary, moist soil with plenty of sunlight but grows best in well-drained soil. Skullcap is harvested in the summer as it comes into flower and dried for later use. Skullcap can be propagated by seed in late spring or by basal cuttings taken 8-10 cm above the ground (PFAF). Cuttings are kept in individual pots in light shade in a greenhouse until they well rooted and can then be planted in the summer.

Agronomic study of the skullcap species *Scutellaria baicalensis* has shown that as planting density increases, the dry weight of roots, leaves and stems per plant and stem diameter all decreased while plant height increased (Lee *et al.* 1988). For purposes of root cultivation, the highest quality and greatest proportion of dry roots were obtained at a row spacing of 30x10 cm spacing.

Products & Uses

• Tea, Tobacco and Insect Antifeedant

Components of skullcap have displayed characteristics which may prove useful for many different types of product, although these currently appear to be quite scarce. The dried flowering aerals are a component of many

herbal tea and tobacco products. The diterpene jodrellins have been shown to have significant antifeedant activity against larvae of *Spodoptera littoralis*, as have scutagalin A and B (Rodriguez *et al.* 1993).

• Medicinal Properties

Skullcap is purported to have sedative and antispasmodic properties and is used in the treatment of nervous disorders including insomnia, headaches, hysteria, convulsions, epilepsy and, more recently, withdrawal from narcotic and alcohol abuse (Johnson *et al.* 1995). Yet despite the traditional uses of skullcap as a sedative and anticonvulsant, there are no documented scientific data to support these uses (Newall *et al.* 1996). Most of the pharmacological activities reported for *Scutellaria* species have nevertheless been attributed to the flavonoid constituents (Newall *et al.* 1996).

However, recent clinical trials of scutellarin have shown it very effective in the cardiovascular system. Clinical trials involving 634 cases of cerebral thrombosis, cerebral embolism and paralysis caused by stroke has been undertaken and an overall effective rate of over 88% was reported following intramuscular, intravenous or oral administration (Peigen *et al.* 1987). Flavonoid glycosides of *Scutellaria galericulata* have also shown antihistaminic activity (Stefan *et al.* 1995).

Skullcap is available locally in capsulated form, as well as in tinctures and teas. It is also a common component of herbal nerve tonics and tablets used to "relieve edginess and headache". The following tea product is one of very many available at health food stores (www.altvita.com).

• Cosmetic Applications

Skullcap has also found application in cosmetic or pharmaceutical products, particularly of dermatological composition, containing liposomes with scutellaria extract. Two patents are registered with this application. Products are described as having anti-inflammatory, anti-allergic and anti-aging properties and can include extracts from *Scutellaria galericulata*, *Scutellaria viscidula* or *Scutellaria baicalensis*.

Chemical Characteristics

Constituents

Essential oil composition (Lawrence *et al.* 1972):

• caryophyllene	29.4%
• beta-farnesene	17.0%
• menthone	10.4%
• 1-octen-3-ol	8.0%
• beta-cubebene	3.3%
• gamma-humulene	2.6%
• germacrene D	2.2%
• limonene	2.1%

Flavonoid constituents (Hetherington *et al.* 1997):

- cutellarin
- galericulin
- galeroside
- baicalin & baicalein
- scutagalins A & B
- jodrellins B & T
- apigenin & apigenin-7-O-glucoside

Other constituents: lignin, resin, tannins

Toxicology

Overdosage of skullcap tincture (>6mL) has resulted in symptoms of giddiness, stupor, confusion and seizures (Newall *et al.* 1996). It has been colourfully described in the CRC Handbook of Medicinal Herbs as "as dangerous as coffee; Duke would not be afraid to drink two cups a day". The FDA, meanwhile, lists Skullcap as a Herb of Undefined Safety (Newall *et al.* 1996).

Commercial Skullcap is often found adulterated with *Teucrium* species. Some species of *Teucrium* have been associated with hepatitis (Newall *et al.* 1996).

Extracts

Water extraction produced a reddish-orange (bronze) colour with a purple hue and an extractive yield of 26.6%. Extract was easily filtered and had a soft, sweet scent.

Ethanol extraction yielded a dark green extract with a yellowish tinge and an extractive yield of 13.9%. Solids are a dark green (black), crystalline and malleable solid with a strong, pungent smell.

Patents

A total of eight patents were found on the US PTO for *Scutellaria* (of which a relevant four are herewithin listed). A search of CIPO yielded no results for *Scutellaria galericulata*, *Scutellaria laterifolia* nor Skullcap. One relevant patent was found for Skullcap, baikal Skullcap in particular, but it will be listed anyway due to the scarcity of other patent information.

- ❖ 5414015 (95/05/09) Konoshima et al.
JAPAN

Anti-skin tumour promoting composition.

- ❖ 00332478/EP B1 (92/03/25) Maybeck A.
FRANCE

Liposomes containing *Scutellaria* extracts; may be selected from *S. baicalensis*, *S. viscidula* or *S. galericulata*.

- ❖ 5447719 (95/09/05) or CA2093442
(93/02/10) Kamataki T. JAPAN

Beta-glucuronidase inhibitor; utilizes extracts of Skullcap root to relieve adverse effects, especially diarrhea.

- ❖ 5773014 (98/06/30) Perrier et al.
Compositions and methods for inhibiting the formation of unwanted skin pigmentation.

- ❖ 5665393 (97/09/09) Chen et al.
Herbal composition for treating prostate carcinoma; a mixture including *Scutellaria baicalensis*.

- ❖ 05643598 (97/07/01) Maybeck A.
FRANCE

Method of skincare utilizing liposomes containing *Scutellaria* extracts.

Cost & Availability

Plant part: blooming aerals

Sask. Availability:

- *Scutellaria galericulata* - This delicate member of the mint family grows at the edge of wetlands and running waters. Its small size and aquatic habitat make for difficult wild harvesting. Marsh Skullcap blooms in July and early August.

- *Scutellaria laterifolia* - This introduced mint is grown by a few medicinal herb farmers in Saskatchewan. The plant thrives here in moist soils and if a contract were arranged, steady and reliable production could be expected.

Sask. Price:

- *S. galericulata*

Harvester Direct, whole: \$15/kg

Dealer's Price, milled and bagged: \$20-\$25/kg

- *S. laterifolia* Certified organic

Grower Direct, dry aerals, whole or milled: \$12-\$15/kg

Dealer's Price, dry aerals, milled: \$15-\$17/kg

- *S. laterifolia* Conventional

Grower Direct, dry aerals, whole or milled: \$9-\$10/kg

Dealer's Price, dry aerals, milled: \$10-\$12/kg

Potential Suppliers:

- ♦ Parkland Botanical, Togo Sask.

(306) 597-2146

- ♦ V.E. Gardens, Burford Ontario

(519) 449-1422 - *S. laterifolia*

- ♦ Buck Enterprises, Le Pas Manitoba

(204) 623-5932

Recommended Website:

The *Scutellaria* Group.

(www.teleport.com/~huritt/page1.html)

- Contains species information and images, a monthly bulletin, seed exchange and germination information and much more.

Special thanks to Dr. Keith Karody of Reed College for use of his Skullcap photograph; one of several great pictures at the following website: (www.reed.edu/academic/departments/biology/courses/BIO332/slideshow/index.html)

Stinging Nettle

Urtica dioica L.

Family: Urticaceae

Common names: Urtica, Common nettle, Greater nettle, American stinging nettle, Hoary nettle

Scientific pseudonyms: *Urtica gracilis* Ait., *Urtica dioica* ssp. *gracilis* (Ait.) Selander, *Urtica procera* Muhl., *Urtica dioica* L. var. *procera* (Muhl.) Wedd., *Urtica holosericea* Nutt.

Stinging nettle is considered by most to be an irritating and noxious weed: a plant to be readily avoided. It is considered one of the most potent plants in producing direct irritation to the skin. However, in other domains, stinging nettle is an economically important and commercially cultivated plant with an extensive history of medicinal usage. It has even been described as one of the most undervalued of economic plants with potential application in a wide range of uses including food, medicines, fibre and hay products.

Description & Habitat

Stinging nettle is a tall, slender perennial herb with an erect square stem reaching a height of 0.5-2 m. The opposite, stalked leaves are 4-15 cm long, pointed and coarsely serrated (Bunney 1992). They are heart-shaped to narrowly lance-shaped with four stipules at each node (Johnson *et al.* 1995). The small green flowers are arranged in panicles in the upper leaf axils; the male clusters are spreading, the female ones pendulous (Bunney 1992). Plants are predominantly monoecious, rarely dioecious (Bassett *et al.* 1977), with sexes on separate plants or in separate spikes on the same plant (Johnson *et al.* 1995).

The irregularly twisted, greyish brown root exhibits distinct longitudinal grooves and has a white, hollow centre (Bissett 1994). Maximum root development occurs in the late spring and early summer, prior to flowering and subsequent seed set. A rhizome planted in the later summer can spread 2.5 m in diameter by the following year (Bassett *et al.* 1977).

The flowers of this species are quite inconspicuous, only 1-2 mm in length, with no petals (Johnson *et al.* 1995). Pollen from stinging nettle is shed in large amounts and is an important contributor to summer hay fever; Bassett *et al.* (1977) report having seen pollen grains catapulted up to 2 cm from the millimeter-long flowers.

On the prairies and in northern areas, stinging nettle flowers from mid-June to late August with each flower producing one achene, and each cluster of four panicles producing approximately 1,000 seeds (Bassett *et al.* 1977). Stinging nettle produces abundant seed but the number will depend on the availability of sunlight: plants growing in the shade produce approximately 500-5,000 seeds per shoot while plants growing in full sunlight produce 10,000-20,000 seeds/shoot (Carey 1995).

When ripe, the fruits are pointed and compressed ovoid in shape, being 1-1.5 mm long and 0.7-1 mm broad. They arise from a panicle-like inflorescence and are sandy coloured, yellow to brown, with a carrot-like odour (Bissett 1994). Seed collected directly from a plant will germinate in 5-10 days and can remain viable following 10 years of storage.

All parts of the plant bristle with stinging hairs, the tips of which break off when touched to release formic acid and other substances that cause blistering, burning and itching of the skin (Bunney 1992), a condition accordingly named urticaria. The hairs consist of a long shaft that narrows towards the point and has a small bulbous tip; the hair just below the tip is not silicified, unlike the rest of the hair, so that the tip is easily broken (Mitchell *et al.* 1979). Indeed, the name *urtica* is derived from the Latin word *uro* (= I burn). Stinging nettle is considered one of the most potent plants in producing direct irritation to the skin (Antonopoulou *et al.* 1996).

The weediness of this herb can be attributed to the vigorous spread of its tough, creeping, branched rhizomes which can establish new colonies from which other species are virtually excluded, although competition from grass species limits the spread of nettle clones (Bassett *et al.* 1977). Stinging nettle possesses strong shoot thrust with the ability to generate mechanical force to extend its shoots vertically into dominant aerial positions (Campbell *et al.* 1992).

Stinging nettle is found across Canada and forms large colonies in orchards, farmyards, old pastures, ditches, woodlands, thickets, streambanks and waste places. On sites west of the Rocky Mountains, the optimum soil pH for stands of stinging nettle was found to range between 5.6-7.6 (Woodland 1975). Stinging nettle will not persist in areas which are saline, or in habitats of low soil fertility (Bassett *et al.* 1977).

Cultivation & History

Stinging nettle is undoubtedly native to North America and is a common, widespread species (Bassett *et al.* 1977). It is widely distributed throughout the temperate zones of both hemispheres: in Europe, Africa, Asia, Australia, North and South America (Bombardelli *et al.* 1997). In some countries, nettles are grown commercially as a source of chlorophyll (Bunney 1992). A rarer, introduced taxon known as European stinging nettle (*Urtica dioica* L. ssp. *dioica* or *Urtica urens*) is also present throughout Canada, although it is confined to a few disturbed habitats in the eastern provinces. Stinging nettle prefers a soil rich in phosphates and nitrogen and must be planted in a deep rich soil if good quality fibre is to be produced (PFAF). Application of nitrogen fertilizers will increase both the stem and leaf yield, while boosting its chlorophyll content (Lieres *et al.* 1994). Stinging nettle's propensity for rich soils has made it a useful indicator species for foresters to indicate which soils are suitable for reforestation (Pigott 1964).

Cultivation of stinging nettle produces a higher yield of foliage than wildcrafting due to higher plant density in cultivated fields (Galambosi 1993). Cultivated plants seem to overwinter well despite intensive fertilization and the collection of 1 or 2 harvests per year. Seeds produced by cultivated plants show a high rate of germination (60-100%), quite suitable for propagation (Galambosi 1993).

Growing seedlings in trays and then planting them out in blocks of 3-5 inches in April proved a better method of establishment in the field than either planting out runners or direct-sowing (Bomme *et al.* 1993). Despite small seed size, direct-sowing could be successful if carried out from the second half of May onwards and having the plots initially covered with a perforated, transparent sheet.

In a 3-year trial period exploring favourable methods of nettle cultivation (Bomme *et al.* 1993), plants transplanted with seedling blocks were found to have highest yields of leaves for pharmacological extraction, although a more recent 6-year study found cultivation method to have no effect on plant composition or content (Bomme 1996). In both cases, however, root yields were highest with crops grown from runners.

Agronomic testing in Russia found that stinging nettle produced high yield on the second and third cuttings (Totev 1964). Especially when growing in rich soils, the plant can spread vigorously and be very difficult to eradicate. Disturbances such as mechanical cultivation will distribute rhizomes through the soil, resulting in the establishment of dense colonies (Carey 1995). When mowed, it sends numerous bushy shoots. However, it will not survive repeated ploughing and mechanical cultivation: several years of such practices will effectively reduce infestation by destroying its extensive rhizome system (Muenscher 1955).

For medicinal purposes, the plant is best harvested in May or June as it is coming into flower and dried for later use (Bown 1995). It should be harvested before the stem becomes woody. The medicinal herb consists of the above-ground parts with stems not more than 3 mm thick (Bissett 1994).

Products & Uses

Food Uses

Young nettle plants (gathered when about 15 cm high) can be used as a spring green vegetable (irritation is eradicated by cooking or drying), making an excellent spinach substitute both in appearance and taste (Woodland 1973). In Germany during World War II, the European stinging nettle was gathered as food for human consumption due to its high nutritive value (Stern 1943). Only young leaves should be consumed, however, as older leaves develop gritty particles called cystoliths which act as renal irritants (PFAF).

Nettle is a very valuable addition to the diet as it is a very nutritious food that is easily digested and high in minerals (especially iron) and vitamins (especially A and C) (PFAF). Tea, wine and a pleasant nettle beer may also be produced for consumption.

• **Hay Crop**

Stinging nettle has been evaluated for use as hay. In Russia, Totev (1964) found nettle hay to be very high in protein and low in fibre while in Italy, Cappa (1965) found that birds fed on nettle meal reached sexual maturity earlier and produced more eggs per bird than birds fed on alfalfa meal. He also found that the amino acids contained in dehydrated meal of stinging nettle were nutritionally superior to the amino acid concentration of dehydrated alfalfa meal.

• **Fibre Applications**

A strong flax-like fibre is obtainable from the stems which can be used for making string, cloth and a good quality paper - although the fibre is less abundant than in flax and is also more difficult to extract (PFAF). Stinging nettle fibers were used by Native Americans in the northwest to make twine, fishing nets and rope (Carey 1995). It is harvested as the plant begins to die down in early autumn and is retted before the fibres are extracted. Following fibre extraction, a variety of by-products can be produced from the remaining biomass including the manufacture of sugar, starch, protein and ethyl alcohol (PFAF).

• **Medicinal Uses**

Nettle has been cited as a folk remedy for a variety of ailments including cancerous ulcers, inflamed and/or edematous tumours, and specifically, cancer of the breast, ear, face, feet, lungs, joints, mouth, nostrils, spleen, stomach, womb, etc. (Duke 1985). It is also listed as a tonic, hypoglycaemic, haemostatic, galactagogue, diuretic and astringent (PFAF). The British Herbal Pharmacopeia lists its specific indication as nervous eczema with anti-haemorrhagic and hypoglycaemic properties.

Such numerous, wide-ranging and often imprecise medicinal indications for nettle herb contrast with the few pharmacological studies carried out so far. Critical appraisal of the therapeutic value of this drug still awaits (Bissett 1994). Listed below, however, are some medicinal properties with actual scientific literature:

Chrubasik & Eisenberg, 1999: *The ingredients of Urtica preparations have proven anti-rheumatic effectiveness accompanied by possible spasmolytic and anesthetic effectiveness.*

- These researchers studied 8,955 patients being treated for rheumatism and found

that in 60% of patients who took non-steroidal anti-inflammatory drugs (NSAIDs) prior to treatment with 0.77g of *Urtica dioica* extract twice daily, the consumption of such drugs could be reduced or entirely eliminated. They concluded that to treat rheumatic pain, phytotherapeutic *Urtica dioica* preparations could allow lower consumption of anti-inflammatory drugs and thus reduce the incidence of their side-effects.

Hryb D.J. et al. 1995: *Extracts from the roots of the stinging nettle are used in the treatment of benign prostatic hyperplasia.*

- Stinging nettle is recommended for benign prostate conditions, especially for treating the congestion and associated difficulties in urination in the early stages or stages I-II of benign prostate hyperplasias (Bissett 1994). Only the aqueous extract has the ability to modulate the binding of sex hormone-binding globulin to its receptor on human prostatic membranes. This interference lowers the increased testosterone metabolism in the hyperplastic tissues, resulting in a rise in free androgen and elimination of the congestion with opening of the urethral obstruction (Bissett 1994). Inhibition is dose related, starting at about 0.6 mg/ml with complete inhibition binding at 10 mg/ml. More recently, however, it has been found that a 20% methanolic extract is most effective with a 51.4% inhibition of induced growth in a mouse benign prostatic hyperplasia model (Lichius et al. 1997).

Balzarini et al. 1992: *A lectin (UDA= Urtica dioica agglutinin) isolated from Urtica dioica was found particularly potent as a selective inhibitor of human immunodeficiency virus types 1 and 2 (HIV-1 and HIV-2), cytomegalovirus (CMV), respiratory syncytial virus (RSV) and influenza A virus-induced cytopathicity at a 50% effective concentration ranging from 0.3-9 ug/mL.*

- Along with some other plant lectins, the UDA protein is assumed to confer its antiviral effect by interfering with the fusion between the virion and the target cell membrane. UDA has also proved to be a potent inhibitor of syncytium formation between persistently HIV-1 and HIV-2 infected cells.

Mittman 1990: Freeze-dried preparations of *Urtica dioica* were found to be more effective than the placebo in improving the symptoms of allergic rhinitis.

- In a double-blind randomized study, individuals suffering from allergic rhinitis were treated with either a stinging nettle preparation or a placebo. Following a week of therapy, stinging nettle was rated higher than placebo in global assessment.

• **Medicinal Products**

Alcoholic extracts of nettle seed are commonly available in European products such as tonics (e.g. Brennesselsamen Vital-Tonikum™ Grandel). Locally available at herb shops are nettle shampoos, tinctures, capsule, a nettle liniment for arthritis and Schoenenberger Nettle juice.

• **Other Uses**

Additional plant extract uses listed by the Plants For A Future database include a very nutritious leaf-derived liquid feed for plants, an insect repellent, a rennet substitute for curdling milk, a waterproofing agent for wood, a yellow dye extractable from the roots and a beautiful permanent green dye extractable from leaves and stems. Some sources mention use as a hair and scalp tonic as it prevents hair from falling out and renders it soft and glossy (D'Amelio 1999). The potential uses of stinging nettle are seemingly endless.

Chemical Characteristics

Constituents

The stinging hairs of stinging nettle contain the compounds acetylcholine (a nervous stimulant), histamine (which causes swelling) and 5-hydroxytryptamine (Mitchell *et al.* 1979). The stinging has also been reported to be caused by formic acid (Bunney 1992).

Seed oil contained (Duke 1985):

- oleic acid 11.5 %
- linoleic acid 73.7 %
- linolenic acid 1.7 %
- saturated acid 7.0 %
(mainly palmitic)
- glycerol 4.5 %
- unsaponifiables 1.6 %

Essential oil constituents (Duke 1985):

- ketones 38.5 %
- esters 14.7 %

- free alcohols 2.0 %
- traces of nitrogenous substances, phenols and aldehydes

Dried, young preflowering plants contain /100g (Duke 1985):

- crude protein 30.4 g
- fats 3.40 g
- cellulose 10.3 g
- N-free extract 39.6 g
- ash 16.3 g
- calcium 2970 mg
- phosphorus 680 mg
- iron 2.2 mg
- magnesium 650 mg
- potassium 3450 mg
- sodium 140 mg
- manganese 4.3 mg
- sulfur 540 mg
- silica 680 mg
- chlorine 270 mg
- beta-carotene 20.2 mg
- vitamin K 0.40 mg
- vitamin C 40.0 mg

Herb constituents (Newall *et al.* 1996):

- Acids: carbonic, formic, silicic, citric, fumaric, glyceric, malic, oxalic, phosphoric, quinic, succinic, threonic and threono-1,4-lactone
- Amines: acetylcholine, betaine, choline, lecithin, histamine, serotonin, a glycoprotein
- Flavonoids: flavonol glycosides (isorhamnetin, kaempferol, quercetin)
- Others: choline acetyltransferase, scopoletin, beta-sitosterol, tannin

Rhizome constituents (Newall *et al.* 1996):

- a lectin (UDA = *U. dioica* agglutinin) composed of six isoelectins; 0.10% of dried material (Bombardelli *et al.* 1997)
- coumarin (scopoletin)
- triterpenes
- beta-sitosterol, its glucoside and six stearyl derivatives
- two phenylpropane derivatives
- six lignans

Chemical composition of Urtica hay (Totev 1964):

- crude protein 21-23%
- crude fats 3-5%
- crude fibre 9-21%

- ash 19-29%
- non-nitrogen 9-21%
extract substances

Toxicology

Stinging nettle is extremely irritating due to the acetylcholine and histamine containing glandular hairs, although irritation is eradicated by drying or heating. An LD₅₀ (mice, intraperitoneal injection) value of 3.625 g/kg body weight has been documented for nettle (Newall *et al.* 1996); in patients with a delicate stomach and in children, nausea and vomiting may occur (Bissett 1994).

In humans, the use of nettles has not been known to cause toxicity other than the local irritation caused by direct contact with the skin (Hamon *et al.* 1985). However, several hunting dogs in the United States died following untreated massive exposure to the hairs of stinging nettle (Anon. 1982). Symptoms precluding death included trembling, pain, slobbering, dyspnea and vomiting followed by death 2-3 days later.

In the US, *Urtica dioica* is classified by the FDA as a Herb of Undefined Safety. In Europe, it is listed as a natural source of food flavouring, a category indicating that insufficient information is available to adequately assess its potential toxicity (Newall *et al.* 1996). The German Commission E monograph (1987) for nettle herb lists no known side effects or contraindications (Bissett 1994).

Extracts

The seed oil obtained by extraction with an organic solvent or by cold-pressing is yellowish green to green in colour, owing to the presence of carotenoids and chlorophyll degradation products (Bissett 1994).

The extracted plant material consisted of the aerial portions of the plant: leaves, inflorescence and stalk. The fibrous stem was quite difficult to grind; producing a very fluffy, cottony material which tended to clog the grinder. Water extraction produced a dark, clear yellow-green solution with an extractive yield of 29.5%. It has a slight odour with a hay-like smell. Filtration of the extract required initial cheesecloth filtration to remove the bulk of the plant material (which was very sludgy due to the fibre content). Ensuing vacuum filtration

required frequent filter paper changes due to a very fine residue.

Ethanol extraction produced a very dark green, clear extract with an extractive yield of 7%. Extract solids are a very sweet-smelling, sticky, glistening dark-green/black gum. Filtration was quite easy while rotavapping the extract down to a more concentrated solution was more of a challenge. The solution was extremely reactive when heated, producing large and unexpected bubbles.

Patents

A total of nine patents for "*Urtica dioica*" and "stinging nettle" were found on the CIPD website and two of relevance on the US PTO. Several European patents were also located.

- ❖ CA2211802 (96/08/15) van den Berghe
BELGIUM

Pharmaceutical composition for the treatment of herpes.

- ❖ CA2184592 (95/10/26) Kopsch *et al.*
GERMANY

Tobacco products, or substances similar to such products, containing natural substances with anti-oxidant properties and process for producing the same.

- ❖ CA1335262 (95/04/18) & 05061491
(91/10/29) Deryabin A.M. USSR

Pharmaceutical composition for treatment of mastitis in animals and humans; comprised of a mixture of medicinal herbs.

- ❖ 05407454 (95/04/18) Cavalieri *et al.* US
Larvicidal lectins and plant insect resistance based thereon; versus common insect pests of agricultural crops.

- ❖ 05407675 (95/04/18) Etemad-Moghadarn
P. IRAN

Method and composition for the scalp and eyebrow region of a subject; for treatment of hair loss.

- ❖ 4323616 (95/01/19) Schreiner E.
GERMANY

Composition containing nucleic acids and derivatives for regeneration of hair.

- ❖ 4323614 (95/01/19) Schreiner E.
GERMANY

Composition containing plant extracts and phospholipids for regeneration of hair and stimulation of hair growth.

- ❖ 5165932 (92/11/24), 00364442/EP B1
(93/03/03) & 05165932 (92/11/24)
Horvath F. HUNGARY

Therapeutical compositions against psoriasis; one of seven named herbs.

- ❖ 4886665 (89/12/12) Kovacs J.
Food additive of pharmaceutical preparation in human health care; mixed with oat extracts.

- ❖ 00341795/EP A1 (89/11/15) &
00414788/EP B1 (94/04/06) & 05316760
(94/05/31) Voerman G.

Mouthcare products; toothpastes, mouthrinses with combination of nettle and *Juniperus communis*.

- ❖ 63710 (76/06/15) Radu et al. ROMANIA
Extraction of chlorophyll from leaves of *Urtica dioica* and production of water-soluble sodium chlorophyllin.

- ♦ Parkland Botanicals, Togo Sask.
(306) 597-2146

- ♦ Wild Botanicals, Murphy, Oregon USA
(541) 846-6395

Recommended Resources:

M Bombardelli E. & Morazzoni P. 1997. *Urtica dioica* L. *Fitoterapia* **68**(5): 387-402.

- an excellent review of the detailed pharmacology and chemistry of stinging nettle

M Bassett I.J., Crompton C.W. & Woodland D.W. 1977. The biology of Canadian weeds. 21. *Urtica dioica* L. *Canadian Journal of Science* **57**: 491-498.

- a very useful guide to the agronomic details of stinging nettle growth and reproduction; as well as details on its history and economic importance

Cost & Availability

Plant parts: leaves only, seed on fine stalks

Sask. Availability: Stinging nettle grows well on moist waste sites, especially on former feeding/bedding yards of cattle. The plant is fully grown in July and is heavy with seed by mid-August.

Sask. Price:

Leaf Only, Conventional

Grower Direct: \$11/kg

Dealer's Price: \$15/kg

Seed on Stalk, Conventional

Grower Direct: \$20/kg

Dealer's Price: \$25/kg

Potential Suppliers:

Trembling Aspen

Populus tremuloides Michaux

Family: Salicaceae

Common names: American aspen, Quaking aspen, Aspen, White poplar, *Populus alba*

Scientific pseudonyms: There are four varieties which are synonymous with *P. tremuloides*: var. *aurea* Tidestr., var. *magnifica* Vict., var. *pendula* Jaeger & Bessner, var. *reniformis* Tidestr. plus an additional nine listed by the USDA.

Trembling aspen possesses manufacturing potential if only based on its widespread availability. Yet despite being one of the most abundant natural tree resources in Canada, the utilization of trembling aspen post-wood production is scarce. Given the enormous availability of leaves and bark as waste materials of the timber industry, trembling aspen has untapped medicinal, insecticidal and potential application as a biomass crop for the production of ethanol, pulp and the generation of electricity and heat.

Description & Habitat

Trembling aspen is a native, deciduous tree attaining heights of 12-18 m and widths of 40-60 cm. It is a slender and graceful tree with a long cylindrical trunk and short rounded crown (Hosie 1969). The trunk has little taper and for most of its length is branch-free and covered with a smooth, pale-white or greenish bark with a waxy appearance that, with age, becomes grey and furrowed into long flat ridges (Hosie 1969). The inner bark loses its spring sweetness as the growing season progresses and becomes bitter. Its leaves are nearly circular, 3-8 cm wide and slightly toothed with a short, abrupt but sharp tip. Its petiole is flattened and slender, usually longer than the leaf blade, thus causing the leaves to characteristically tremble in the breeze.

Seedlings may reach 15-60 cm in their first year with roots extending 15-25 cm deep and 40 cm laterally. Roots grow more rapidly than shoots; some seedlings show little top growth until their third year (Brinkman *et al.* 1975). Trembling

aspen first flowers at 2 to 3 years of age: the minimum age for production of large seed crops is 10 to 20 years and maximum seed production occurs at about 50 years (Tirmenstein 1988). There are 3 to 5 year intervals between heavy seed crops. Flowers are drooping catkins which appear in early spring well before the leaves; male and female catkins appear on separate trees (Johnson *et al.* 1995). Sustained air temperatures above 12°C for approximately six days apparently triggers catkin flowering; these will mature in 4-6 weeks.

The fruit is a green tufted capsule, 3-5mm long, bearing six to eight seeds; a single female catkin usually bears 70 to 100 such capsules (Tirmenstein 1988) and a female tree can produce several millions of seeds annually (Johnson *et al.* 1995). The seeds are covered by a cottony mass commonly seen in June and July (Royer *et al.* 1996). Seed will disperse a few days after they ripen for a duration of 2 to 3 weeks (Perala 1990) and remain viable for three days to three weeks. Germination success of 80-95% is reported under laboratory conditions (Tirmenstein 1988) but in outdoor conditions, most seed seldom find appropriate conditions for germination (Johnson *et al.* 1995).

The root system of trembling aspen is shallow, very wide-spreading and commonly produces root suckers (Hosie 1969). In such a way, it can produce entire stands of clones which can cover several hectares and are best characterized in the spring or autumn, when all members of a clone produce or drop their leaves at the same time (Johnson *et al.* 1995). Heavy grazing of leaves, buds, twigs and bark by moose and deer tends to slow this development, but seldom heavily enough to check its spread.

Cultivation & Habitat

Trembling aspen is the most widely distributed tree in North America (Tirmenstein 1988). It is found in a range of soils from shallow, rocky or clay soils to rich sandy ones but grows best in rich porous soils with plenty of lime (Elias 1980) and an alkaline pH of 6-9. Trembling aspen is a very shade-intolerant species.

Aspen naturally regenerates by seed and by sprouting from the roots. Root sprouting is the most common method of regeneration. Saplings may begin producing root sprouts at 1 year of age and have enormous potential for suckering: 20,000-30,000 sprouts per acre is typical the

first year following top-kill (Jones 1976), although most will die off within the first few years. Stump and root crown sprouting is rare in older trees, but saplings sometimes sprout from the stump and root crowns, as well as from the roots.

Trembling aspen is also commonly established from seed. Optimum conditions for germination and seedling survival include a moist mineral seedbed with adequate drainage, moderate temperature and freedom from competition (McDonough 1979). The minimum planting density per acre is 300 while the maximum should not exceed 1200. Seedling transplanted onto disturbed sites have shown good establishment (Chan *et al.* 1989).

Planting of seedlings has some advantages over vegetative cuttings; in large-scale greenhouse production, trembling aspen seedlings are more economical to establish and grow (Fung *et al.* 1993). Cuttings can be slow to establish an adequate root system (Schier *et al.* 1985)

Products & Uses

• Wood Products & Biomass Crop

Trembling aspen is one of the most important timber trees in the East (Tirmenstein 1988). Its wood is used primarily for particleboard, especially wafer boards and oriented strandboards, and for pulp. Aspen wood is very versatile and is used to make specialty items including excelsior, matchsticks, animal beds, chopsticks, crafts, venetian blinds and tongue depressors.

Scientists have developed hybrid poplars as potential biomass crops for production of ethanol, pulp and the generation of electricity and heat. Aspen thrives on marginal soil and cool climates, annually yielding up to 3.7 tonnes of biomass/ha. The use of trees for fuels, although less efficient than crops, may be a more reasonable fuel alternative for Canada in that the trees are able to occupy the huge areas of marginal land unsuitable for crops (Small 1999).

• Bioremediation

Aspens are unique in their ability to stabilize soil and watersheds; trees produce abundant litter that contains more nitrogen, phosphorus, potash and calcium than leaf litter of most other hardwoods (Tirmenstein 1988). The litter

decays rapidly, forming a nutrient-rich humus that may amount to 25 tonnes per acre (oven-dried basis).

• Medicinal Uses

Trembling aspen has an entry in the British Pharmacopeia, a text published by the British Herbal Medicine Association, which lists it as having antirheumatic, anti-inflammatory, antiseptic and astringent action with a specific indication for rheumatoid arthritis. Marked anti-ulcerative properties of trembling aspen bark were recently demonstrated on mice and rats with stress-, reserpine-induced and acetylsalicylic ulcers. (Zueva *et al.* 1997). The gastroprotective effects of the extract reduced both the number of animals with mucosal ulcers and the number of ulcers.

All of these properties were long before known to the Woods Cree and the Chipewyan who utilized the inner bark for treatment of rheumatism, infection and colds (Johnson *et al.* 1985).

The white powdery substance found on the trunks of trembling aspen can be used to stop cuts from bleeding while fresh leaves are used directly to bee stings to reduce irritation (Royer *et al.* 1996). Tea from the root bark is used as a treatment for excessive menstrual bleeding; leaf buds are used as a salve for colds, coughs and irritated nostrils and root is poulticed and applied to cuts and wounds (Foster *et al.* 1990).

• Food Uses (PFAF)

The nutritional content of aspen varies seasonally, by plant part and clone, but the overall energy and protein values of trembling aspen are generally rated as fair. In winter, however, the protein levels of trembling aspen browse is high relative to other species. The inner bark of trembling aspen can be collected in spring, dried and ground into a powder which can be used in combination with other flours to make bread. Catkins can be eaten cooked or raw, although they taste a bit bitter. Its sap can be tapped and used as a drink.

The Council of Europe lists trembling aspen as a source of food flavouring, such that it can be added to foodstuffs in small quantities, with a possible limitation of an active principle (as yet unspecified) in the final products (Bissett 1994).

• Insecticide

The phenolic glycosides tremulacin and salicortin are known toxins of some insect larvae (Scriber *et al.* 1991). Ingestion of these

glycosides by larvae causes death or suppression of their growth rates, suggesting possible selective application of these compounds in environmentally-friendly insecticides.

Chemical Characteristics

Constituents

Mean composition of trembling aspen terminal shoots (Schwartz *et al.* 1988):

• Dry matter	43.6%
• Gross energy	5.1 kcal/g
• Crude protein	7.9%
• Neutral-detergent fibre	54.9%
• Acid-detergent fibre	40.1%
• Lignin	10.5%
• Ash	1.9%
• In-vitro digestibility for moose	42.0%

Leaf content; percent dry weight (Rickleft *et al.* 1982):

• Moisture	55.6 %
• Lipid	2.6 %
• Carbohydrates	14.9 %
• Crude fibre	26.3 %
• Hemicellulose	6.6 %
• Holocellulose	13.7 %
• Lignin	12.6 %
• Polyphenols	5.3 %
• Nitrogen	2.3 %
• Phosphorus	0.19 %
• Potassium	0.67 %
• Calcium	0.77 %
• Magnesium	0.24 %
• Ash	5.77 %

Bud exudate components (Hetherington *et al.* 1997):

• *simple phenolics* 10-85%
-including benzoic acid, ferulic acid, caffeic acid, coumaric acid, benzyl benzoate, ferulyl alcohol, benzyl coumarate, ferulyl benzoate, benzyl ferulate and caffeate

• *complex phenolics* 1-50%
-including isosakuranetin, sakuranetin and kaempferol

• *hydrocarbons* 3-54%

Additional compounds reported include:

- salicin (~2.4%)
- tremuloidin, tremulacin and populin (benzoate derivatives)
- triploside
- trichocarpin
- salicortin
- salireposide
- trichoside
- pyrocatechol
- glucose ester of coumaric acid

Salicin, salicortin, tremuloidin and tremulacin are the four major phenol glycosides found in trembling aspen (Clausen *et al.* 1989). Aspen internodes, rather than leaves, are used as the source of phenol glycosides because internodes have a predictable phenol glycoside content, while leaf glycoside content fluctuates dramatically during the growing season (Clausen *et al.* 1989).

Toxicology

Young seeds were once chewed and swallowed by Cree women trying to induce an abortion (Johnson *et al.* 1995). Otherwise, piles of aspen logs have been observed to produce a dark, watery leachate which proved acutely toxic to trout and *Daphnia* at a concentration of 1% and 2% respectively (Taylor *et al.* 1996). Inhibition of bacterial metabolism began at concentrations below 0.3%, while it was less toxic to plant life with inhibition of algal growth at 12-16%. The leachate was rich in phenols (30 mg/L), organic carbon (2,480 mg/L) and organic nitrogen (13 mg/L), but much of the toxic effect must be attributed to other, unidentified constituents (Taylor *et al.* 1996).

No side-effects are reported in human use but side-effects and signs of toxicity normally associated with salicylates, such as gastric and renal irritation, hypersensitivity, blood in the stool, tinnitus, nausea and vomiting may occur (Newall *et al.* 1996).

Extracts

Bark

Water extraction of ground trembling aspen bark produced a sweet-smelling extract (almost cinnamon-like), with an opaque, dull-yellow colour with an extractive yield of 22%. Aside from a slight clumpiness, the residual extracted material looked little different from the initial fibrous, yellow powder obtained by grinding dried bark.

Ethanol extraction yielded a clear, bright yellow extract with an extractive yield of 37.8%. Solids are an orangy-brown gummy solid with a very woody smell. There was also very little change in the appearance of the starting material.

Leaves

Water extraction yielded a clear, golden extract with a pleasant, nonspecific tea smell. It has an orange-brown colour and an extractive yield of 26%. The ground leaf residue did not change much during the extractive process; it remained a light, green-brown powder with some light yellow stalk material.

Ethanol extraction yielded a dark green (with some yellow), cloudy extract with an extractive yield of 29.5%. Solids are a glistening, dark green, sticky substance which appear black. Residual material appears lighter than the original.

Patents

A few patents have been found for trembling aspen. Three relevant patents were located of a total of 8 found for poplar on the US PTO, and one specific for *Populus tremuloides* was found on CIPO:

- ❖ 5884584 (99/03/23) Feldman P.
Animal litter created from a mixture of alfalfa and pine.
- ❖ CA2204384 (96/09/04) Jones S. CANADA
Medicinal composition for treatment of diabetes; uses an extract derived from a *Populus* species (*P. tremuloides* is also listed specifically) along with *Heracleum lanatum*.
- ❖ 5271355 (93/12/21) Billings L.D.
Absorbent mat with wood and peat.

- ❖ 5135578 (92/08/04) Billings L.D.
Method of cleaning oil slicks and chemical spills; use of bark-based material on water/oil or on beaches for cleanup.

Cost & Availability

Plant part: bark only, leaves and twigs

Sask. Availability: Very common tree in aspen parkland and boreal mixedwood forest eco-regions. Twigs and leaves harvest season July-September. Bark harvest late May through June. Bark may be available as a by-product from sawmills and fence-post operations. Twig and leaf harvest would be more difficult to organize, but wild harvesters would be attracted to large, firm orders.

Sask. Prices:

Bark - dry, milled and bagged: \$1.50-\$2.00/kg
Twigs and leaves - dry, milled and bagged: \$8-\$10/kg

Potential Suppliers:

- ♦ Parkland Botanicals, Togo Sask.
(306) 597-2146
- ♦ Buck Enterprises, Le Pas Manitoba
(204) 623-5932

White Spruce

Picea glauca (Moench) Voss

Family: Pinaceae

Common names: Canadian spruce, Western white spruce, Alberta white spruce, Black Hills spruce, Skunk spruce, Cat spruce, Porsild spruce

Scientific pseudonyms: *Picea alba*, *Picea canadensis* (P. Mill.) B.S.P. (Three additional varieties are listed by the USDA).

If only because of the immense quantities available, coniferous foliage utilization is a subject of some importance (Shaw 1951). Sawmills and pulp mills annually produce hundreds of millions of pounds of waste bark and foliage which have potential for use as sources of bioactive chemicals for use in environmentally-friendly insecticides, essential oil and antibacterial products. With such a readily available source of material, otherwise discarded or wasted, the potential for value-added processing of white spruce is considerable.

Description & Habitat

White spruce is a large, native evergreen tree whose average height is 24 m (80 ft). It has a long, straight and tapering trunk (usually 60 cm wide) with a uniform conical crown and branches that spread or droop slightly to the ground. It sports needle-shaped leaves, green to bluish-green in colour, which are typically 2 cm long, stiff and four-sided (Hosie 1969). The needles project from all sides of the branches. Its trunk is covered with a thin, scaly bark that is greyish-brown in colour. On mature trees, the bark is quite thin, usually less than 8 mm thick (Sutton 1969); inner bark has a pinkish tinge while the outer bark has loose ash-brown scales (Johnson *et al.* 1995).

Its root system is shallow with many tough, pliable and wide-spreading lateral shoots (Hosie 1969). Rooting depth is commonly between 90-120 cm, but taproots and sinker roots may

descend up to 3 m (Nienstaedt *et al.* 1990). Twigs are usually hairless and whitish-grey to yellowish in colour with a smooth, shiny texture. Its white wood is light, soft, resilient and straight-grained (Hosie 1969).

The bloom period of white spruce occurs in late spring, with fruit and seed production proceeding in summer. Cones are 5 cm in length, long and cylindrical. They hang from branches of the upper crown and open in autumn, falling during the winter or the following spring. They are light-brown with round, close-fitting scales which spread almost at right angles and are easily crushed (Hosie 1969). Pollen cones are pale red (Johnson *et al.* 1995).

Pollen shedding occurs in May, June or July; a temperature-dependent process with much variation. Seeds are about 3 mm long with a 6-9 mm wing; there are approximately 226,000 seeds per pound (Safford 1974). The winged-seeds are dispersed by wind and although most are found within 65 m of its source, some have been found as far away as 400 m (Uchytel 1991).

White spruce is a very common and abundant tree characteristic of the boreal forest region, though it can be found almost everywhere in Canada (Hosie 1969). It has a transcontinental distribution across northern North America, exhibiting considerable geographic variation although is largely confined to well-drained uplands, river terraces and floodplains (Uchytel 1991). It grows well on loams, silt loams and clays; rather poorly on sandy soils (Eyre 1980). It is a very long lived tree with a lifespan of 50 to 100 years (AAFRD).

Cultivation & History

White spruce is a fast growing tree, especially when young, with annual height increases of up to 1 m, although its growth slows considerably with age (Mitchell 1975). White spruce is considered a long-lived, shade-tolerant climax species (Uchytel 1991). Stands often decline after approximately 200 years, probably due to spruce budworm outbreaks. The acceptable planting density is 300 - 700/acre (NPDC); or 300-1000/m² (Duke 1983). Growth requirements include: high fertility, a soil pH range of 4.7-6.5 and minimum precipitation of 22 cm (NPDC).

The following table describes the division of biomass between tree structures when growing on soils of differing quality; MT/ha (Duke 1983):

	<i>Sandy soil</i>	<i>Loam</i>
• foliage	11.7	17.4
• branches	30.1	35.8
• bole bark	12.0	11.2
• bole wood	89.0	91.0
• stumps and roots	31.0	35.0
TOTAL BIOMASS	175	190

Seed production has been variously cited as beginning at 4 years of age (Nienstaedt *et al.* 1972) and at approximately 20 years (Elias 1980), though it is generally agreed that reliable crops may take twice that long, after which heavy crops are produced every 2-5 years.

White spruce seed remains viable for up to 10 years when stored in sealed containers in a cool dry environment. Seeds require moist, cool stratification for 60-90 days to break dormancy (Sutton 1969). Although no elaboration is given, seed from Alberta is purportedly an exception, requiring no pre-sowing treatment (Uchytel 1991).

Additional planting suggestions:

- fresh seeds should be sown in autumn
- stored seed should be sown as early in the year as possible
- seedlings should be planted in individual pots and grown in a greenhouse for their first winter
- planting into permanent position may follow in early summer.

White spruce can also be readily propagated by rooted cuttings (Nienstaedt *et al.* 1990), although for adequate natural regeneration, mineral soil seedbeds are required (Sutton 1969). Cuttings of semi-ripe terminal shoots, 5-8 cm long, should be taken in August and will root the next spring. Cuttings of mature terminal shoots, 5-10 cm long, can be taken in September or October and will take 12 months to establish.

Products & Uses

• Essential Oil Products (Shaw 1951)

It has been estimated that 5 million pounds of volatile oil could be produced from the black spruce cut annually in Ontario alone. It is doubtful whether the present consumers (mostly perfume and flavour industries) could

absorb anything near this amount, although the market for the oil could be expanded by more efficient production methods or by the development of new uses for the oil or its constituents.

Although white spruce has a lower yield than other conifers, it possesses excellent odour and is of commercial value. It is of interest to note that some small commercial installations in Canada are operating at a profit on yields in the order of 0.5%. As well, because white spruce is harvested in large quantity for the lumber industry, its bark and foliage is available in enormous quantities as a by-product of this industry. The oil has been used for scenting deodorants, room sprays, incenses and others (Duke 1983).

Bornyl acetate is a valuable component of white spruce leaves and is present in high amounts. It is a basic ingredient in almost all perfume compositions possessing a pine odour and is used for the synthesis of camphor. A UK company, Sourcerer, which is a chemical product manufacturer and distributor, lists on its website that no bulk suppliers have been found for this product. Its methacrylate ester component has attracted attention as a copolymer with butadiene for the manufacture of synthetic rubber and for the fabrication of transparent plastics with optical properties similar to glass.

• Wood Products

White spruce is one of the most important trees in Canada for pulpwood and lumber (Hosie 1969). It is a commercial tree used for general construction; its logs are used extensively for cabin construction and spruce wood has also been used for specialty items such as sounding boards, paddles and oars, cabinets, boxes and food containers (Uchytel 1991).

In Saskatchewan, manufacturing is carried out for both uses. Pulping involves, essentially, removal of components other than the cellulosic fibres. Lumber preparation involves de-barking and cutting-to-size of the trunks. The resonance of the wood, and its capacity to transmit vibrations, make it an ideal wood for guitars, violins, piano and soundboards (Lauriault 1989). The wood was used by the Cree to make canoe paddles, fishnet floats and canoe ribs (Royer *et al.* 1996).

• **Insecticide**

Monoterpenes found in the oleoresin of white spruce bark have marked toxicity versus the spruce beetle, *Dendroctonus rufipennis* (Werner 1995). The bark constituent limonene was the most toxic and inhibitory monoterpene effective at a concentration of 20 ppm. Beta-phellandrene, limonene and myrcene were most toxic to the beetle *Dendroctonus simplex*.

Sawmills and pulp mills produce hundreds of millions of pounds of waste bark annually. This bark could be used as a continuing source of bioactive chemicals as there is real potential to exploit forest-based, naturally occurring insecticidal compounds within the forest industry itself - for the control of economically-significant forest pests and in the production of seedlings used in reforestation (Wills *et al.* 1999).

• **Food Uses** (PFAF)

Spruce oil, distilled from the leaves and twigs, is used in the food industry to flavour chewing gum, ice cream, soft drinks and sweets. Young male and female catkins can be eaten cooked or used as flavouring, while the inner bark can be dried and ground into a powder and used as a soup thickener or added to cereals and breads.

Gum from the tree trunk is a suitable substitute for chewing gum. A refreshing tea, rich in vitamin C, can be made from the young shoot tips. Shoots are used to make spruce beer; a favoured remedy for scurvy in the days of the European invasion of North America (Duke 1983).

Benjamin Franklin's Spruce Beer recipe:

For a cask containing 80 bottles, take one pot of spruce essence and 13 pounds of molasses; mix them well together in 20 pints of hot water and stir together until they make a foam. Pour into the cask you will then fill with water, add a pint of good yeast, stir it well together and let stand 2 or 3 days to ferment. After a few days, it will be ready to be put into bottles, that must be tightly corked. Leave 10 or 12 days in a cool cellar, after which the beer will be good to drink.

• **Medicinal Uses**

White spruce has long been used medicinally by the Woods Cree and the Chipewyan who utilized the inner bark against arthritis pain, to draw out infection, to treat various skin diseases, to soothe sore throats and as a general medicinal

wash (Johnson *et al.* 1985). Recent investigation of this traditional use has found that pitch preparations of white spruce have definite antimicrobial activity (Ritch-Krc *et al.* 1996). Tea made from the young shoot tips is also claimed to have antiseptic properties (PFAF).

Chemical Composition **Constituents**

Oil constituents (Hetherington *et al.* 1997):

Compounds	Yield from:		
	needles	buds	twigs
Volatile Oil	0.2-0.5%	0.5%	0.6%
• alpha-pinene	6.2%	29.0%	22%
• beta-pinene	2.8%	12.9%	16%
• limonene	15.3%	31.3%	37.5%
• myrcene	10.2%	16.8%	21%
• camphor	40.6%	-----	-----
• 3-carene	-----	9.0%	6.5%
• bornyl acetate	12.1%	-----	-----
• camphene	8.8%	-----	-----

Yield of oil at various times; ml of oil per 100g of green foliage (Shaw 1951):

	February	April
• White spruce	0.25	0.45
• Black spruce	0.86	1.42
• White cedar	0.95	0.70
• Hemlock	0.98	0.68

White spruce needle composition (Ellison 1966):

Constituent	Range	Mean
• Protein	5.5-8.1%	6.32%
• Fat	2.8-4.1%	3.34%
• Crude fibre	21.0-25.9%	23.5%
• Ash	2.6-4.4%	3.27%
• N-free extract	61.4-65%	63.5%
• Calories	486-506	494.8
(Kg calories/100g)		

Yield and properties of the oil of white spruce cones (Shaw 1952):

• yield	0.154 %
• bornyl acetate	9.1 %
• borneol	14.4 %
• carvone	1.8 %
• citral	3.1 %

White spruce seed composition; percent dry weight (Bennett 1966):

• Moisture	4.92%
• Ash	5.04%
• Total nitrogen	3.80%
• Soluble nitrogen	0.14%
• Reducing sugar	0.42%

• Sucrose	1.96%
• Xylan	3.78%
• Lignin	14.3%
• Ether extract	44.2%

Composition of the epicuticular wax of *Picea glauca* (Tulloch 1987):

• Yield (% dry weight)	0.7%
• methyl esters	6%
• hexyl and octyl esters	5%
• aldehydes	3%
• nonacosan-10-ol	30%
• free acids	3%
• diterpene acids	10%
• free alcohols and diols	2%

The relative amounts of beta-pinene, limonene and myrcene in the volatile oil of the buds change significantly during fall and winter (von Rudloff 1972). In contrast, the volatile oil of the leaves and twigs remains constant in quantitative composition during late summer, fall and winter. During May, substantial amounts of sesquiterpenes are present in the new growth, but these appear to be metabolized further as the summer progresses (von Rudloff 1972).

The chemical composition of white spruce has been found to be influenced by ecological factors and age. Branches from isolated sun-exposed trees yielded 20% more oil than trees in dense bush, while branches from 25 year-old trees yield twice as much oil as a 45 year-old specimen (Duke 1983).

Toxicology

No toxicity is reported by the USDA (NPDC). Data do exist for many of the individual constituents identified from spruce, however. Spruce dust and needles cause contact allergies in approximately 5.5% of the general population, while the same components may also aggravate the symptoms of asthma (Duke 1983). Plasters have also caused redness and skin irritation in some.

Extracts

The water extraction of ground, dried white spruce bark produced a dark, opaque extract with an orange-brown colour and a strong sappy, fresh-cut wood smell. The extractive yield was 24.3%. It was difficult to filter, with much foaming (indicative of saponins) and very fine residue.

The ethanol extract produced a dark crimson colour with an extractive yield of 15.6%. Extract solids are a crystalline solid, appearing black in colour but actually a very dark red, with a very woody smell.

Patents

A search of the US PTO yielded over 30 patents when searched for spruce, but none relevant to any manufacturing endeavours. CIPO lists 8 patents when searched for white spruce; mostly for forestry and wood products, and while white spruce is listed as a wood source, none involve a specific product to be derived from this tree.

❖ 11139939 JP (99/05/25) Ikemizu et al.
JAPAN

Hair tonic with hair root cell activating action.

Cost & Availability

Plant part: bark

Saskatchewan Availability: Common tree species in boreal forest eco-region. Bark may be available as a by-product from sawmills and post-treating mills. Many trees are harvested in late-May and June.

Saskatchewan Price: Dealer's Price, dry and milled: \$0.85-\$1.50/kg

Potential Suppliers: n/a

Recommended Resources:

N Duke, James A. 1983. Handbook of Energy Crops. Unpublished. NewCROP: New Crop Resource Online Program. Centre for New Crops and Plant Products. Purdue University. (<http://www.hort.purdue.edu/newcrop/>)

- an excellent source of information on the use, folk medicine, toxicity, chemistry, cultivation, harvesting and more of *Picea* species

M Shaw, A.C.

1951. Production of Essential Oils from Coniferous Foliage. *Canadian Chemistry and Process Industries*.

1952. The preparation and composition of some Canadian coniferous oils. *Pulp and Paper Magazine of Canada*.

- older but with very modern ideas for the utilization of forestry industry by-products

Yellow Evening Primrose

Oenothera biennis L.

Family: Onagraceae

Common names: Fever plant, Scabish, Scurvish, Tree primrose, Sundrop tree primrose, King's Cureall, Nightwillow herb, Sundrop

Scientific pseudonyms: *Oenothera pycnocarpa* Atkinson & Bartlett, *Oenothera muricata* L.

Yellow evening primrose is cultivated in a number of countries due to its high content of gamma-linolenic acid, which has many nutritional and pharmaceutical applications. The demand for the oil continues to grow and yellow evening primrose and borage are its two chief sources. However, biennial evening primrose was discarded from Western Canadian evaluation trials by Agriculture Canada in 1986 because it was proven non-winter hardy at a trial plot in Manitoba. While considerable amounts of the alternative crop borage have been grown in Saskatchewan, it has been suggested that evening primrose is a better diversification crop for Canada than borage (FERENCE 1989). Recent research by Agriculture Canada has also focused on evening primrose with the development of a production system, identification of superior biotypes and investigation of major pests.

Description & Habitat

Yellow evening primrose is a native biennial herb, 0.5-1.5 m tall, which grows from a stout, fibrous, yellow taproot. In its first year of growth, it forms a low-lying leafy rosette from which, in its second year, it grows an erect branching stem with a spike of large, bright yellow flowers. New shoot growth from the overwintered rosette stage usually commences in late spring; in the south of Canada this is usually in late May or early June. It has alternate, narrowly lance-shaped to oblong

leaves, 2-15 cm long, which may be sparsely to densely hairy and stalkless (Johnson *et al.* 1995). Leaf edges are wavy and may be minutely toothed at its margins.

Records indicate that flowering will begin in mid- to late July with mature seeds produced by mid-August (Hall *et al.* 1988). Although evening primrose will flower and bear seed only once in its lifetime, it does so in spectacular fashion. Flowers are borne in spikes at its stem tips with the uppermost flowers coming out first. Two to five bright yellow flower open at dusk and wilt the following morning, to be replaced by others the following evening. Its flowers release a strong lemon scent which attracts insects, particularly moths, for fertilization (Briggs 1986).

Fruit is an oblong, hairy capsule, 2-3 cm long, which shatter easily to scatter seed. Each plant will produce approximately 140 capsules, with each containing 180 orange-brown seeds (Hall *et al.* 1988). A dormant evening primrose seed can remain viable in soil for at least 80 years (Darlington *et al.* 1961), no doubt contributing to the species' classification by Environment Canada as a moderately invasive weed.

Research trials in Finland showed evening primrose to be a high-yielding species with an annual fresh phytomass of 33-65 tonnes/ha and a dry phytomass of 8-10 tonnes/ha. Fresh and dry root yields were 5-12 tonnes/ha and 1-3 tonnes/ha in the first year and 16-30 tonnes/ha and 4-8 tonnes/ha in the second (Galambosi 1989).

Yellow evening primrose is found on roadsides, field edges and waste places. It prefers well-drained sandy loam and warm sun, although like most weeds, it can thrive in almost any soil situation.

Cultivation & History

Yellow evening primrose is a widespread weed native to the northern temperate zone of North America, from British Columbia through to the Atlantic coast. It was introduced into Europe as early as 1614 where it has long been cultivated as an ornamental plant and is now naturalized throughout the temperate regions of both hemispheres (Hall *et al.* 1988). Later, evening primrose was even recommended to American gardeners as "German rampion" (Johnson *et al.* 1995).

In the 1960's, yellow evening primrose began to gain scientific notoriety in Yugoslavia for its pharmaceutical properties, later undergoing commercial development in the U.K., Netherlands and Hungary in the 1970's and 1980's (SAF). Yellow evening primrose has accounted for 90% of the gamma-linolenic acid market, though it is now getting competition from such crops as borage (Fairbairn 1995). The annual Canadian and US production is estimated to be 160-200 tonnes, with Canadian production centred in Nova Scotia and Ontario (SAF). A commercially viable yield is considered to be in excess of 600 lbs/acre.

Hybrid evening primrose, the biennial variety of commercial value, was found in the 1980's to have poor over-wintering hardiness in Western Canada when evaluated in field trials in Morden, Manitoba. Consequently, it was long ago discarded from western Canadian evaluation trials by Agriculture Canada. Growers interested in the gamma-linolenic acid market are currently encouraged to consider borage seed production by Saskatchewan Agriculture & Food. Borage, *Borago officinalis* L., is an ancient, essentially undomesticated species native to the Mediterranean cultivated for forage and medicinal uses. Most borage oil is produced in Europe and Asia, but since the crop seems well adapted to the cool growing conditions in parts of the prairies, it has potential for further development in Canada (Small 1999). Borage is already a successful crop in Saskatchewan with the development of Bioriginal, a leading supplier of borage oil. The main drawback is that only 5-15% of the borage seed crop can be collected by conventional means due to seed shattering and an indeterminate growth rate (Small 1999). Its expected yield is but a paltry 100-200 lbs/acre.

However, the interest in developing yellow evening primrose does not seem to have much waned. If the conditions for growing yellow-evening primrose can be incorporated in a successful production strategy, it is quite possible that a new crop species will be born (Nonnecke 1992). As a biennial plant with very quirky germination requirements, it first and foremost must behave as an annual if it is to claim legitimacy.

Yellow evening primrose can be direct-seeded and behave as a biennial, or it can be transplanted and grown as an annual. In Ontario, the crop is started mid-winter in greenhouses and transplanted into the fields in

early spring. Seeds are sown in inch-deep soil in early spring, transplanting the seedling 3 inches apart when an inch high into a sunny position (AAFRD). Such production permits the desired annual harvesting of the seed the same year it was planted thereby eliminating both the need of devoting a field to the crop for two seasons to achieve a single harvest (SAF), and the risk that the crop will not survive the winter.

While there are no evening primrose varieties able to withstand extremely cold over-wintering conditions, researchers in Ontario have had good stand success by planting seeds in early to mid-August and allowing plants to grow to about 3-4 inches in diameter prior to fall freeze up (Bob Roy, personal communication). A good seed to soil contact is necessary, as is prevention of winter wind erosion.

A propagation method has been facilitated by the laboratory micropropagation of seeds on media. Seedlings are then transferred ex-vitro and field grown to produce a viable crop. Seed content of gamma-linolenic acid and oil were even slightly higher than in seeds from field-cultivated plants (Skrzypczak *et al.* 1994).

Contrary to other oil plants, yellow evening primrose is not influenced by varying temperature which can desaturate fatty acids, especially gamma-linolenic acid (Reiner *et al.* 1988). Nor is the amount of oil in the seed influenced by time of transplanting: only in one year of three did the linolenic acid content of the oil decrease with transplanting delay (Roy *et al.* 1994).

The taproot can be easily collected in the fall; 1 lb can be collected in 15 minutes (Duke 1992). Seed pods are harvested, but variance of the seed maturity makes the process difficult. High stem and seed moisture contents (15-31%) at harvesting causes blockage in machinery and storage problems. Following swathing, pods and stems can take 30 days to dry down from 75% to 30% moisture content: chemical dessication has successfully reduced pod moisture, but not that of the stem (Dodd *et al.* 1986).

Products & Uses

• Medicinal & Nutraceutical

Traditionally, evening primrose has been utilized as a vegetable and medicinal herb both by native people in North America and by

Europeans following its introduction. The whole plant was used to prepare an infusion with astringent and sedative properties considered to be an effective treatment for asthmatic coughs, gastrointestinal disorders, whooping cough and as a sedative pain killer (Briggs 1986).

The many and diverse healing properties of evening primrose have since been substantiated by many scientific studies. Based on a summary by Briggs (1986) in the Canadian Pharmaceutical Journal, following is a brief overview of the benefits of evening primrose oil:

Table 1: Reputed Uses of Evening Primrose Oil (with reference):

A. Cardiovascular/ Circulatory System

- decreases blood pressure (Horrobin 1990)
- decreases platelet aggregation (Horrobin 1990)
- significant reduction in the risk of coronary heart disease has been found with dietary supplementation of foods or oils rich in linolenic acid (evening primrose oil contains 72%); (Newall *et al.* 1996)

B. Systemic Health

- gamma-linolenic acid produces a highly significant improvement in all features of atopic eczema, especially in itch relief (Newall *et al.* 1996)
- diabetic neuropathy can be either prevented or reversed by the provision of gamma-linolenic acid as evening primrose oil (Jamal *et al.* 1986)
- administration of gamma-linolenic acid has been reported to prevent or attenuate renal damage (Newall *et al.* 1996)
- evening primrose oil slows the progression of multiple sclerosis with a beneficial effect on the severity and duration of relapses (Li Wan Po 1991)
- evening primrose oil has been found to possess both antisecretory and anti-ulcerogenic effects (Al-Shabanah 1997)

C. General Health

- significant beneficial effects have been demonstrated on post-viral fatigue syndrome of viral infections (Newall *et al.* 1996)
- in-vitro studies suggest evening primrose oil slows development or kills malignant cells

- administration of evening primrose oil with co-factors enhanced the improvements of schizophrenic symptoms (Newall *et al.* 1996)

D. Miscellaneous

- reduced symptoms of benign breast disease
- animal studies suggest that it may be beneficial in rheumatoid arthritis
- prevents hangovers from alcohol
- alleviates mental symptoms of premenstrual syndrome

The beneficial effects of evening primrose oil in treating atopic eczema and mastalgia have been recognized with product licenses granted to evening primrose oil preparations for these indications (Newall *et al.* 1996). Such beneficial effects are purportedly based on the supplementation of the essential fatty acid gamma-linolenic acid (GLA), which is a constituents of membranes in all body tissues. GLA is also the precursor to the prostaglandins and leukotrienes whose activities include anti-inflammation, immunoregulation, vasodilatory properties, inhibition of platelet aggregation and cholesterol biosynthesis and finally hypotension (Briggs 1986).

A reduced production of GLA has been observed in a number of clinical situations including aging, diabetes, cardiovascular disorders, high cholesterol, high alcohol intake, viral infections, cancer, and others. Direct dietary supplementation with GLA effectively bypasses the rate-limiting conversion step and has a beneficial effect on the ratio of inflammatory: non-inflammatory prostaglandin compounds.

• Food Uses (PFAF)

The entire yellow evening primrose plant is edible. Its nutritious and wholesome root has been used as a vegetable with a peppery flavour (Briggs 1996). It is described as fleshy, sweet and succulent. Young shoots can be used in salads, although some suggest they should not be eaten. Flowers are sweet and used in salads or as a garnish while young seedpods can be steamed.

Pressed seed residue, already extracted of oil, is a waste byproduct of the herbal-pharmaceutical industry. In an effort to utilize this plentiful resource, the nutritive composition of extracted seed was investigated as a possible source of feed for farm animals. Despite the surprisingly high biological value of native and boiled seeds, it was found that raw evening primrose seed residue could not be a valuable source of

protein due to the high content of anti-nutritive substances and low protein digestibility (Hanczakowski *et al.* 1993).

Chemical Constituents

Constituents

Seed oil constituents (Newall *et al.* 1996):

- Fixed oils 14%
 - cis-linoleic acid (LA) 72% (65-80%)
 - cis-gammalinolenic acid (gamolenic acid, GLA) 2-16%
 - oleic acid 9%
 - palmitic acid 7%
 - stearic acid 3%

Gamma-linolenic acid is not a normal constituent of vegetable oils (Briggs 1986). Seed lipids of evening primrose, in contrast to those of most higher plants, contain predominantly gamma- rather than alpha-linolenic acids (Mukherjee *et al.* 1987).

Pressed seed residue content; percent dry matter (Hanczakowski *et al.* 1993):

- crude protein 22.2 %
- ether extract 17 %
- fibre 22 %
- ash 8.4 %

Lipid content in developing seeds (Mukherjee *et al.* 1987):

<i>Weeks after flowering</i>	<i>Lipid content (%)</i>
3	1.5
4	3.4
5	7.9
6	11.9
7	15.3
8	16.5
mature seed	24.9

Toxicology

Evening primrose oil appears to well-tolerated and virtually non-toxic with very few, minor side effects including mild gastrointestinal effects, indigestion, nausea and headache (Newall *et al.* 1996). As well, animal studies have indicated that evening primrose oil is non-teratogenic. The USDA lists evening primrose as having no toxicity (NPDC).

Extracts

Water extraction of ground, dried flowering yellow evening primrose aerials yielded a very sticky, opaque and viscous light brown-yellow extract with a mild tea smell and an extractive yield of 20.8%. Filtration was quite difficult due to the thick consistency and required cheesecloth filtration. Solids have a rich, spicy smell and are a crystalline orange-brown colour.

Ethanol extraction yielded a dark, clear emerald-green extract with an extractive yield of 14%. Dried solids are a black crystalline solids with a green tinge, dull odour and sticky feel.

Patents

On the CIPO website, 32 patents were found when searched for evening primrose (compared to one on the US PTO). Many of these deal with various oil-oriented processes and fractionations; not products in particular. Presented below are various patents which deal with specific yellow evening primrose products:

- ❖ CA2225352 (99/07/30) Han et al.
CANADA

Vegetable derived petroleum jelly replacement.

- ❖ 5738859 (98/04/14) Posner R.
Cosmetic composition.

- ❖ 5639460 (97/06/17) Raymond H.C.
Aqueous plant extract having antiviral activity; an extract of *Oenothera caespitosa* for treatment of Herpes simplex lesions, Epstein-Barr and varicella.

- ❖ CA2141126 (96/07/27) Lazarowych et al.
CANADA

Combinational drug for treating migraine and other illnesses.

- ❖ CA2194876 (96/03/07) Leung et al. US
Bioadhesive-wound healing composition; including evening primrose oil.

- ❖ CA2191603 (96/02/08) Martin A. US
Antifungal-wound healing composition and methods for preparing and using same.

- ❖ CA2191604 (96/01/11) Martin A. US
Anti-inflammatory wound healing compositions and methods for preparing and using same.

- ❖ CA2187628 (95/10/12) Demichele et al.
US

Nutritional product for treatment of ulcerative colitis and use thereof.

❖ CA1332568 (94/10/18) Pereira M.C. UK
Cosmetic composition.

❖ CA1275006 (90/10/09) Horrobin P.F.
CANADA

Food production; method of maintaining hens or other domesticated birds for egg production with feed supplemented with gamma-linolenic acid.

❖ 62210995 JP (87/09/17) Yamada et al.
JAPAN

Production of gamma-linolenic acid by tissue cultivation.

❖ 62210992 JP (87/09/17) Yamada et al.
JAPAN

Production of purple pigment.

❖ 87126933 (87/06/09) Kojima T. JAPAN
Manufacture of oxidation-resistant *O. biennis* oil.

❖ 60153774 JP (85/08/13) Mochizuki et al.
JAPAN

Effect for low blood cholesterol, preventing hypertension, rejuvenating and activating cells.

❖ CA1160570 (84/01/17) Horrobin P.F.
CANADA

Pharmaceutical and dietary compositions.

❖ CA1157773 (83/11/29) Horrobin P.F.
CANADA

Pharmaceutical and dietary compositions containing thioproline; for treatment of cancer.

❖ CA1125171 (83/06/08) Horrobin P.F.
CANADA

Pharmaceutical and dietary composition; treatment of cancer or inflammatory disorders with combinational use of gamma-linolenic and zinc, beta-lactam, antibiotics or others.

❖ CA1117012 (82/01/26) Horrobin P.F.
CANADA

Pharmaceutical and dietary composition; treatment of schizophrenia, obesity, menstrual or skin disorders with combinational use of gamma-linolenic and zinc, beta-lactam, antibiotics or others.

❖ 4058594 (77/11/15) & 03993775
(76/11/23) Williams J. UK

Immunosuppressive agents; gamma-linolenic or derivative and linoleic acid as a method of control of neurological disorders and tissue transplants. Oil of *O. biennis* is a convenient source.

Cost & Availability

Plant part: blooming aerals

Sask. Availability: Plant grows wild in alfalfa and native grasses, but these stands may be too sparse to allow commercial wildharvest. Cultivation in Sask. Is possible, but percent active ingredient in plant materials may be too low for successful extraction.

Sask. Price:

Conventional

Grower Direct, baled or milled: \$6/kg

Availability Outside Sask: This crop was grown in Nova Scotia during the 1990s under contract to a seed oil processing firm. Most of the evening primrose oil now sold in supplement industry originates in China. Blooming aerals, baled, also available from china.

Potential Suppliers:

♦ Wang Fang/DOSIC Tel: 441-3629406/07
Email: osic@pub.dl.Inpta.net.cn

Recommended Resources:

M Briggs C.J. 1986. Evening primrose: la belle de nuit, the king's cureall. *Canadian Parmaceutical Journal* **119(5)**: 249-254.

- a very good review of the medicinal properties of evening primrose

M Fairbairn C. 1995. The grower's guide to herbs and spices. University Extension Press. University of Saskatchewan, Saskatoon.

- provides valuable information on the marketing, production, agronomy and economics of growing evening primrose in Saskatchewan

N Hall I., Steiner E., Threadgill P. & Jones R. 1988. The biology of Canadian weeds. 84. *Oenothera biennis* L. *Canadian Journal of Plant Sciences* **68**: 163-173.

Yellow Sweet-Clover

Melilotus officinalis (L.) Lamarck

Family: Fabaceae (Leguminosae)

Common names: Melilot, Official melilot, Trefle d'odeur jaune (Quebec), King's sweet-clover, Ribbed melilot

Scientific pseudonyms: *Melilotus arvensis*

Yellow sweet-clover has historically been represented as a bothersome and noxious weed. Indeed, its persistence and ability to persist in extremely adverse conditions is the lore of legendary weediness. However, the same attributes are also the lore of legendary crop attributes. In France and Germany, yellow sweet-clover is an administered medicine whose utilization dates back to the ancient Greeks. In Saskatchewan, it is utilized as a pasture crop, but little else.

Description & Habitat

Yellow sweet-clover is an introduced biennial legume that forms a rosette of leaves in its first growing season following germination. Much of the growth in the first year is dedicated to the expansive root system which increases the percentage of available carbohydrates (Smith *et al.* 1948). On the prairies, it sometimes behaves as an annual, flowering the first year.

Growth in the second year consists almost entirely of aerals (Smith *et al.* 1965). In the spring, the over-wintering crown buds give rise to rapidly growing stems; normally producing a tall flowering stalk which set seed after which time they die (Turkington *et al.* 1978). It has a tall, grooved, angled and branched stem which grows to a height of 50-150 cm. The alternate, stalked leaves are trifoliate with oblong, toothed leaflets and stipules joined to the stem (Bunney 1992).

The percentage total biomass assigned to each part of the plant at the peak of flowering is 11% underground structures, 52% stem, 7% leaves and 30% flowers, seeds and associated

structures (W. Abrahamson in Turkington *et al.* 1978).

It has a narrow root crown producing 1-10 upright stems and has short, erect rhizomes and a deep taproot that exceeds 120 cm in depth. Contractile roots keep the crown 5 cm or more below the surface in the fall, protecting it from severe winter conditions (Turkington *et al.* 1978). Yellow sweet-clover possesses root nodules and has a symbiotic relationship with *Rhizobium* bacteria which are able to convert atmospheric nitrogen into a form which can be utilized by the plant (Turkington *et al.* 1978). This ability permits yellow sweet-clover to grow on nitrogen-deficient soils.

Flowers are yellow, 4-6 mm long, and arranged in long slender spikes in the upper leaf axils (Bunney 1992). They appear in June and July, remaining in fresh condition for approximately two days (Stevens *et al.* 1926). Flower induction in biennial sweet-clovers is influenced by ambient air temperature: low temperatures (<13.3°C) will retard flowering while temperatures >15°C tend to trigger flowering (Smith 1942).

The fruit is a pale brown, hairless ovoid pod with transverse wrinkles containing oblong seeds with a shallow lateral notch at one end (Turkington *et al.* 1978). Usually, one seed is produced per fruit but some may have two or three. Seed production varies widely from fewer than 100 per plant to 350,000 per plant; seeds can remain viable for several years (Turkington *et al.* 1978). The first seeds will typically mature by late July, continuing to ripen until the late autumn (Turkington *et al.* 1978). The seeds are "hard" (impervious to water) and require scarification before germinating (Sullivan 1992).

Sweet-clover possesses typical weedy attributes: it reproduces in large numbers, has allelopathic properties (inhibits growth of surrounding plants), is persistent and grows singly or in small clumps along roadside edges, railways, pastures and disturbed areas (Turkington *et al.* 1978). It is considered a noxious weed in many areas. At the seedling stage, yellow sweet-clover is a poor competitor with other vigorous species and are restricted to disturbed, ploughed or eroded ground. Second year plants grow rapidly in the spring and can compete more effectively.

Yellow sweet-clover is drought-tolerant, only requiring enough moisture to establish after which they can continue to develop under extremely dry conditions (Butovssii 1971). Yellow sweet-clover will not persist in shaded areas: isolated plants growing in partial shade are less vigorous than those in the open and produce very few seeds (Turkington *et al.* 1978).

Cultivation & History

Yellow sweet-clover is native to Eurasia but currently is naturalized from Ireland, through Europe and widely distributed in North America. In Canada, plants occur from Newfoundland to British Columbia and north to southern Northwest Territories (Turkington *et al.* 1978). The use of sweet-clover plants dates back to the ancient Greeks who utilized the plant for medicinal purposes (Smith *et al.* 1965).

The earliest report of *Melilotus* in North America was in 1664 by Boucher but the species was not identified (Stevenson 1969). Although yellow sweet-clover was cultivated as a fodder crop in Prince Edward Island before 1850 (Erskine 1960), it has more often than not been reported as a bothersome weed. Historically, yellow sweet-clover has been cultivated as forage crops for cattle and, to a lesser degree, for honeybees (Turkington *et al.* 1978).

Its only mode of reproduction is by seed, although cross-fertilization is necessary. Seed spread rate is rapid and seedling vigour high (NPDC). Pre-soaking seeds will accelerate its germination (which takes about 2 weeks); seeds should be sown in spring to mid-summer. Seed production is influenced by many ecological factors including weather and soil conditions, plant spacing, management practices and the number of pollinating insects (refer to Smith *et al.* 1965 for full details).

Seedlings can appear in any month of the year, but major sprouts of germination occur in early spring with a second smaller sprout possible in late fall. Seedling appearing from late March to early May have the best chance of survival but are invariably biennial. In a greenhouse experiment, approximately 30 plants started from seedlings in either fertile loam or clay soil survived and grew in each square meter (Turkington *et al.* 1978). In sandy or stony soil, young seedling mortality is high and flowering plants are often large and widely spaced: seldom more than 1 or 2 per square meter.

Sweet-clover has strong, deep taproots and can grow well on soils of moderately low fertility (Smith *et al.* 1965). It grows rapidly and is easy to establish, preferring a well-drained to dry neutral or alkaline soil (pH 5-8) in a sunny position (Bown 1995). If cut before flowering, the plants will grow for at least another year before dying (PFAF). Its growth rate following harvest is described as slow.

Products & Uses

• Food Uses

Crushed dried leaves can be used as a vanilla flavouring in pudding and pastries while young, fresh leaves are eaten in salads. Young shoots and seedpods can be cooked and consumed as a vegetable, while flowers (raw or cooked) can provide an aromatic quality to some tisanes and is also valued as a flavouring. Yellow sweet-clover is also a valuable plant for the production of honey, as it is highly attractive to a number of bee species and halictids and is an excellent source of nectar. The dried herb is also used to flavour various cheeses and put in tobacco snuff; seeds may be substituted for Tonka beans (Duke 1985).

• Medicinal Uses

The German Commission E monograph lists yellow sweet-clover as having the following indications:

- ⇒ disorders accompanying chronic venous insufficiency such as pains and a feeling of heaviness in the legs, night cramps, itching and swellings
- ⇒ in the supportive treatment of hemorrhoids and lymphatic congestion
- ⇒ external use for the treatment of contusions, sprains and superficial effusions of blood

The medicinal properties of yellow sweet-clover are attributed to its coumarin and flavonoid content. These have been shown to produce a reduction of lymphoedema and improve the symptoms of mastalgia in 74% of cases with no reported adverse effects (Mazzocchi *et al.* 1997). In France and Germany, it is administered in diseases of blood and lymphatic vessels (Dombrowicz *et al.* 1991).

Recent research in Russia is also studying the immunocorrecting, antianemia and adatogetic effects of some polysaccharide constituents of yellow sweet-clover (refer to Podkolzin *et al.* 1996). Yellow sweet-clover seeds have even been suggested as a remedy for the common cold (Duke 1985).

Yellow sweet-clover is a component of some prepared herbal remedies (teas), mostly to enhance the taste, but also as an active drug (Bissett 1994). It has a bitter, somewhat pungent, and salty taste. Extracts are components of several anti-phlebitis remedies, most of which have a standardized coumarin content, e.g. Venalot™ (capsule, ampoules, liniment), Phlebodril-Creme, Pascovenol™ (dragees, drops), etc (Bissett 1994). The plant is used in asthma cigarettes and as a decoction in lotions and enemas (Duke 1985).

• **Additional Uses**

Leaves can be dried and used as an insect repellent, especially to repel moths from clothing. However, yellow sweet-clover was found to have only a short-term repellent effect (Detmers *et al.* 1992). The constituent dicoumural is an active ingredient in rat poisons.

Yellow sweet-clover is also amongst the most productive pasture plants if properly managed; providing good quality hay rich in protein and minerals and satisfactory for good quality silage (Turkington *et al.* 1978).

Chemical Characteristics **Constituents**

Dry seed content (Duke 1985):

• Protein	12.8 - 41.6%
• Fat	1.9 - 7.60%
• Ash	4.0 - 14.3%

Yellow sweet-clover hay content (Duke 1985):

• Moisture	5.4%
• Protein	20.3%
• Fat	4.6%
• N-free extract	38.8%
• Fibre	22.0%
• Mineral matter	9.4%

Protein content and digestible protein of yellow sweet-clover (National Acad. of Sciences 1971):

• Crude Protein	15.0%
• Digestible protein - cattle	10.2%
- goats	10.8%
- horses	10.5%
- rabbits	10.4%

Total phenolic acids (mg/100 g) of dried Melilotus herb (Dombrowicz *et al.* 1991):

• salicylic	29.6 mg
• p-hydroxybenzoic	5.7 mg
• melilotic	167.8 mg
• p-hydroxyphenylacetic	26.3 mg
• vanillic	15.2 mg
• gentisic	3.8 mg
• o-coumaric	30.9 mg
• protocatechuic	14.3 mg
• syringic	10.9 mg
• p-hydroxyphenyllactic	9.9 mg
• p-coumaric	44.3 mg
• gallic	11.9 mg
• ferulic	44.4 mg
• caffeic	84.9 mg
• sinapic	19.9 mg

• Also reported are canavanine, trigonelline, cordianine, uric acid, allantoinic acid, quercetin, kaempferol, mucilage, choline, resin and tannin.

• The plant contains 0.9 to 2% coumarin, melilotol, melilotine, melilotic acid, coumaric acid, hydrocoumarin, melilotoside (Duke 1985).

Coumarin is concentrated in flower buds and fresh leaves from the tips of branches; roots, stems and mature leaves have very low levels (Linton *et al.* 1963). Most or all of the coumarin of the intact plant is held as the glucoside melilotoside.

Toxicology

Yellow sweet-clover has no known contraindications or side effects when used for medicinal purposes (Bissett 1994). However, when cut for feed, molding can occur due to the succulent stems which metabolizes coumarin to produce the toxic metabolite dicoumarol. Dicoumarol interrupts vitamin K use in animals and subsequently affects blood-clotting abilities (CPPI).

The leaves and stems are considered to be toxic. General symptoms for poisoning of cattle or horses include anemia and hemorrhage (CPPI).

In humans, 4,000 mg of coumarin induces headache, nausea, vomiting and weakness (Duke 1985). The USDA lists its toxicity as moderate (NPDC).

Extracts

Ground, dried flowering aerials has a distinctive sweet, moldy hay smell and is a yellowish-green powder with bits of straw. Water extractive produced a light orange-brown extract with an extractive yield of 42.1%. It was very foamy until filtration (indicative of saponins) and had a sweet, cooked vegetable odour. Residual plant material is slightly clumpy, but otherwise similar to the starting material. Dried solids have an enormously sweet and pleasant smell and are of a yellowy-orange, crystalline appearance.

Ethanol extraction produced a clear, emerald green extract which was easily filtered and had an extractive yield of 11.9%. Dried solids consists of an orange and yellow iridescent solid with a black, splotchy deposit which together form a sticky, black gum with a strong, sweet smell. Residual extracted material is notably yellow but similar in original consistency.

Patents

There was but a single patent found for yellow sweet-clover originating in North America; a Canadian patent issued in 1985. No patents were found for "Melilotus" or "sweet (-) clover" on the US PTO website nor were any relevant patents found for the same terms on CIPO. There were, however, several patents found that originate in Japan.

❖ 05163115 JP (93/06/29) Yokota T. JAPAN
Beautifying and whitening cosmetic.

❖ 05078230 JP (93/03/30) Yokota T. JAPAN
Skin-beautifying cosmetic; suppresses skin inflammation by UV radiation and suppress melanin generation.

❖ 04305518 JP (92/10/28) Migamoto T.
JAPAN

Haircare cosmetics; hair-growing effects, falling hair-preventative effect and dandruff-preventative effect by blending a meliloti extract which promotes scalp peripheral blood flow and activation of hair mother cell.

❖ 91161412 (91/07/11) Shinomiya T.
JAPAN

Cosmetic moisturizer containing vitamin E and Melilotus officinalis extracts.

❖ 02282332 JP (90/11/19) Sawai et al.
JAPAN

Crude drug-applying preparation; therapy or mitigation of inflammation outside the human body.

❖ CA1192108 (85/08/20) MacLean M.
CANADA

Substitute tobacco product for use as cigar tobacco, pipe tobacco or chewing tobacco.

❖ 58134012 JP (83/08/10) Yamazaki et al.
JAPAN

Composition for oral cavity application; prevention and remedy of periodontitis.

❖ 7305023 (73/02/13) Kurigama et al.
JAPAN

Skin cosmetic containing extract of Melilotus officinalis.

Cost & Availability

Plant Part: blooming aerials

Sask. Availability: Fairly common forage crop, usually grown with a nurse crop for establishment year. Both conventional and certified organic material available.

Sask. Price:

Conventional

Grower-Direct, 90% pure, baled: \$60-\$80/tonne

Certified Organic

Grower Direct, 90% pure, baled: \$110-\$150/tonne

Potential Suppliers:

Check SAF website, Western Producer Classified, OPIS, Organic Chapters and Organic Certification Agencies for growers.

Recommended Resources:

M Turkington R.A., Cavers P.B. & Rempel E. 1978. The biology of Canadian weeds. 29. Melilotus alba Desr. and M. officinalis (L.) Lam. Canadian Journal of Plant Sciences 58: 523-537

References

For a complete listing of references included in this report, please contact the Saskatchewan Nutraceutical Network at the following address to request a copy:

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Email: info@nutranet.org
Website: www.nutranet.org

Appendix A:

Summary of Species Data

Plant	Common Name	Plant type	Status	Part Used
<i>Acorus calamus</i>	Calamus root	Semi-aquatic herb	Native	Rhizome/root
<i>Arctostaphylos uva-ursi</i>	Bearberry	Forest evergreen shrub	Native	Leaves/berries
<i>Astragalus membranaceus</i>	Astragalus	Cultivated herb	Introduced	Rhizome/root
<i>Cannabis sativa</i>	Hemp	Cultivated herb	Introduced	Seed
<i>Caragana arborescens</i>	Caragana	Cultivated/wild shrub	Introduced	Leaves and twigs
<i>Carum carvi</i>	Caraway	Cultivated herb	Introduced	Seed
<i>Cladina stellaris</i>	Reindeer lichen	Forest shrub lichen	Native	Aerials
<i>Coriandrum sativum</i>	Coriander	Cultivated herb	Introduced	Seed
<i>Cornus stolonifera</i>	Red-osier dogwood	Wild/cultivated shrub	Native	Leaves and twigs
<i>Fagopyrum esculentum</i>	Buckwheat	Cultivated herb	Introduced	Seed
<i>Grindelia squarrosa</i>	Gumweed	Wildflower/forb	Native	Flowering aerials
<i>Hedysarum alpinum</i>	Hedysarum	Forage/wild herb	Native	Flowering aerials
<i>Ledum groenlandicum</i>	Labrador tea	Forest evergreen shrub	Native	Aerials (leaves)
<i>Linum usitatissimum</i>	Flax	Cultivated herb	Introduced	Seed
<i>Medicago sativa</i>	Alfalfa	Cultivated/wild herb	Introduced	Aerials
<i>Melilotus officinalis</i>	Yellow sweet-clover	Cultivated/wild herb	Introduced	Flowering aerials
<i>Oenothera biennis</i>	Yellow evening primrose	Cultivated wildflower	Native	Flowering aerials
<i>Phalaris canariensis</i>	Canaryseed	Cultivated/wild grass	Introduced	Seed
<i>Picea glauca</i>	White spruce	Wild evergreen tree	Native	Bark
<i>Populus tremuloides</i>	Trembling aspen	Wild deciduous tree	Native	Bark and leaves
<i>Salix interior</i>	Sandbar willow	Wild deciduous shrub	Native	Leaves and twigs
<i>Scutellaria galericulata</i>	Skullcap	Wild/cultivated herb	Native	Flowering aerials
<i>Silybum marianum</i>	Milk thistle	Wild herb/weed	Introduced	Aerials
<i>Symphytum officinalis</i>	Comfrey	Cultivated/wild herb	Introduced	Aerials (leaves)
<i>Trigonella foenum-graecum</i>	Fenugreek	Cultivated legume	Introduced	Seed
<i>Urtica dioica</i>	Stinging nettle	Wild/cultivated herb	Native	Aerials

Appendix B:

Summary of Experimental Data

Plant	Extractive Yield (Dry Matter)		Cytotoxicity (Reactivity)	
	Water	Ethanol	Water	Ethanol
<i>Acorus calamus</i>	24.0%	15.6%	n/a	n/a
<i>Arctostaphylos uva-ursi</i>	39.9%	45.5%	none	slight
<i>Astragalus membranaceus</i>	37.5%	10.0%	none	none
<i>Cannabis sativa</i>	n/a	n/a	n/a	n/a
<i>Caragana arborescens</i>	28.5%	13.9%	none	none
<i>Carum carvi</i>	11.9%	9.6%	none	none-slight
<i>Cladina stellaris</i>	3.6%	8.0%	none-slight	none-slight
<i>Coriandrum sativum</i>	13.0%	20.0%	none	slight
<i>Cornus stolonifera</i>	25.3%	23.9%	slight	slight
<i>Fagopyrum esculentum</i>	9.8%	13.1%	slight	slight
<i>Grindelia squarrosa</i>	20.4%	27.9%	none	none
<i>Hedysarum alpinum</i>	22.8%	15.4%	none	none
<i>Ledum groenlandicum</i>	22.0%	26.0%	none	none
<i>Linum usitatissimum</i>	37.8%	41.6%	none	none
<i>Medicago sativa</i>	42.1%	11.9%	none-slight	none-slight
<i>Melilotus officinalis</i>	34.4%	20.7%	none-slight	slight
<i>Oenothera biennis</i>	20.8%	14.0%	slight	slight
<i>Phalaris canariensis</i>	28.4%	7.9%	none	slight
<i>Picea glauca</i>	24.3%	15.6%	slight	slight
<i>Populus tremuloides</i> - bark	22.0%	37.8%	slight	mild
<i>Populus tremuloides</i> - leaves	26.0%	29.5%	mild-moderate	slight
<i>Salix interior</i>	24.4%	29.1%	slight	none
<i>Scutellaria galericulata</i>	26.6%	13.9%	none	slight
<i>Silybum marianum</i>	11.8%	40.0%	slight	slight
<i>Symphytum officinalis</i>	28.9%	37.9%	none-slight	none
<i>Trigonella foenum-graecum</i>	11.9%	10.2%	none	none
<i>Urtica dioica</i>	29.5%	7.0%	none-slight	none

n/a - Calamus samples were not available for cytotoxicity due to the prolonged inability to expediently acquire a sample. Testing of hempseed was also unattainable due to time restrictions related to the requirement of a permit acquisition from Health Canada.

Cytotoxicity: The assessment of cytotoxicity (or biological reactivity) is based on cytopathic effects incurred by a confluent culture of fibroblast cells under and around a sample of the plant extract. Cytopathic effects include cellular degeneration and malformation, cellular lysis or presentation of a clear zone where the plant sample was applied. A sample is considered cytotoxic (bioreactive) if reactivity is graded as greater than mild. Reactivity is measured based on the following guidelines:

Reactivity	Conditions of cell culture
None	No detectable zone around or under specimen; all cells healthy and confluent.
Slight	Some malformed or degenerated cells under specimen.
Mild	Zone limited to area under specimen.
Moderate	Zone extends 0.5-1.0 cm beyond specimen.
Severe	Zone extends greater than 1.0 cm beyond specimen.

Appendix C:

Summary of Plant Cost & Availability

Plant	Common Name	Harvester' Price	Dealer's Price	Availability
<i>Calamus calamus</i>	Calamus root	\$31/kg whole	\$40/kg whole or milled	poor
<i>Arctostaphylos uva-ursi</i>	Bearberry	\$7/kg whole	\$11/kg milled	fair; \$19/kg Ontario
<i>Astragalus membranaceus</i>	Astragalus	\$11/kg whole*	\$14/kg milled*	good candidate crop
<i>Cannabis sativa</i>	Hemp	\$1.2-1.5/kg seed; \$60-80/tonne straw		good candidate crop
<i>Caragana arborescens</i>	Caragana	\$5/kg chipped	\$7-9/kg	great
<i>Carum carvi</i>	Caraway	\$0.66-0.75/kg* seed	\$1-1.15/kg* seed	good
<i>Certified organic aerals in bloom</i>		\$350-500/tonne	\$600-900/tonne	good
<i>Cladina stellaris</i>	Reindeer lichen	\$12-15/kg	\$25-30/kg	good
<i>Cladina spp.</i>		\$2.5/kg	\$5-6.50/kg	good
<i>Coriandrum sativum</i>	Coriander	\$0.33-0.37/kg	\$0.44-0.53/kg	good
<i>Cornus stolonifera</i>	Red-osier dogwood	\$9/kg	\$12-14/kg	great
<i>Eragopyrum esculentum</i>	Buckwheat	\$7-8/bu*	\$8-10/bu*	great
<i>Erindelia squarrosa</i>	Gumweed	\$4.50/kg baled	\$11-13/kg	good
<i>Hedysarum alpinum</i>	Hedysarum	\$7.00/kg	\$8-11/kg	good
<i>Ledum groenlandicum</i>	Labrador tea	\$11/kg	\$15/kg	good
<i>Linum usitatissimum</i>	Flax	\$0.25-32/kg*	\$0.35-49/kg*	great
<i>Medicago sativa</i>	Alfalfa	\$1.90-2.40/kg seed*	\$2.75-3.75/kg*	great
		\$60-80/tonne forage*		great
<i>Melilotus officinalis</i>	Yellow sweet-clover	\$60-80/tonne baled*		great
<i>Oenothera biennis</i>	Y. evening primrose	\$6/kg		good
<i>Phalaris canariensis</i>	Canaryseed	\$0.23-0.31/kg	\$0.35-0.45/kg	great
<i>Picea glauca</i>	White spruce		\$0.85-1.50/kg milled bark	great
<i>Populus tremuloides</i>	Trembling aspen		\$1.50-2/kg milled bark	great
			\$8-10/kg leaves/twigs	great
<i>Salix interior</i>	Sandbar willow		\$3-4/kg milled bark	great
			\$8-10/kg leaves/twigs	great
<i>Scutellaria galericulata</i>	Marsh skullcap	\$15/kg whole	\$20-25/kg milled	poor
<i>Scutellaria laterifolia</i>	Blue skullcap	\$9-10/kg*	\$10-12/kg*	good
<i>Silybum marianum</i>	Milk thistle	\$33-40/kg; \$19/kg Ontario; \$300/tonne Bulgaria		good
<i>Symphytum officinalis</i>	Comfrey			
<i>Trigon. foenum-graecum</i>	Fenugreek	\$0.40-0.50/kg*	\$0.53-0.67/kg*	good
<i>Urtica dioica</i>	Stinging nettle	\$11/kg (leaf only)	\$15/kg (leaf only)	fair
		\$20/kg (seed on stalk)	\$25/kg (seed on stalk)	fair

*certified organic also available (at higher cost)